COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

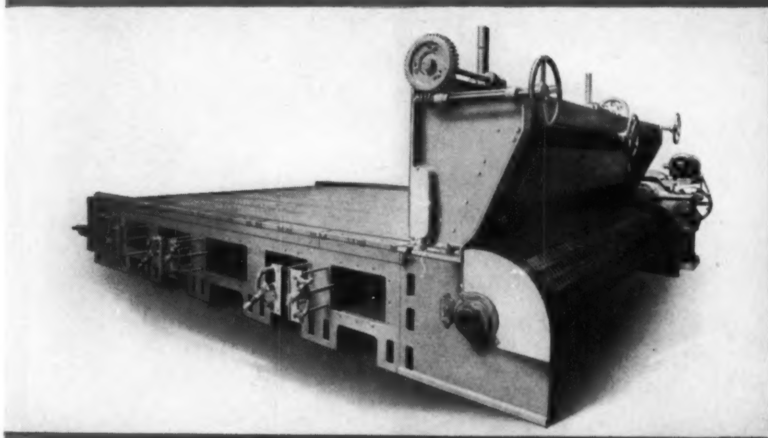
November, 1941

Welding ends of economizer loops to stub tubes on header of a very high pressure boiler; the clamps are for alignment during welding

Firing with Multiple-Retort Underfeed Stokers

Adjustment of Pulverized-Fuel-Burning Equipment

WHEN CONDITIONS CALL FOR CHAIN OR TRAVELING GRATE STOKERS



C-E Chain Grate Stokers have a grate surface which consists of a number of small link castings held together by through rods to form a continuous, flexible chain. Special driving links, located at intervals across the width of the stoker, engage a series of driving sprockets carried on the front shaft.

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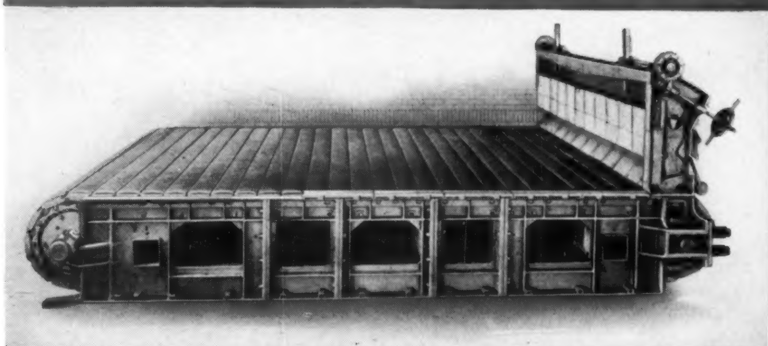
ANY TYPE
ANY SIZE



C-E Traveling Grate Stokers are distinguished by their grate surface which consists of small castings supported by transversely arranged grate bars carried by sprocket-driven chains located between the stoker side frames.

Here's another classification of stokers that bears out C-E's reputation as "Headquarters for all Types of Fuel-Burning Equipment."

Among *Traveling Grate Stokers,* C-E offers types to serve the approximate range of capacities from 150 hp up to units producing 200,000 lb of steam per hr or more. The Coxe Stoker is the most widely known of the traveling grate types with more than 2,300 having been installed under boilers with an aggregate heating surface of nearly 10,500,000 sq ft. It is without equal for burning small sizes of anthracite and coke breeze; also is well suited to lignite and some free-burning bituminous coals.

C-E Traveling Grates are forced-draft stokers with the air supply to the entire grate surface under zoned control.

Among *Chain Grate Stokers,* C-E offers types to serve the approximate range of capacities from 150 boiler hp up to units producing 275,000 lb of steam per hr or more. The Green Stoker alone has a record of 4,300 installed under boilers with an aggregate heating surface of over 10,000,000 sq ft. C-E Chain Grate Stokers are particularly well suited to the use of free-burning bituminous coals. They are available in both forced and natural-draft designs.

Whether your conditions of load and the available fuel point to traveling grate, chain grate or any other type of stoker, look to C-E for an installation that can be relied upon to give the best operating and economic results. A-611

Over 16,000 C-E Stokers have been installed to serve 4,500,000 rated boiler hp

COMBUSTION ENGINEERING

200 Madison Avenue **New York, New York**

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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CONTENTS

FOR NOVEMBER 1941

FEATURE ARTICLES

EDITORIALS

DEPARTMENTS

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EDITORIAL

Power Pool in the South

Because of the drought and consequent power shortage that for some months past has threatened those sections of the South largely dependent on hydro power, the Federal Power Commission recently ordered the Duke Power Company to deliver additional energy to the TVA and one of the large aluminum plants, as well as to certain other utilities supplying defense demands. Curtailment in the use of power by non-defense consumers of TVA and some of these companies was thereby deferred.

It now appears, however, that power rationing is inevitable, pending the completion of additional steam capacity now on order or under construction. This rationing was scheduled to be undertaken early this month by the OPM from Atlanta as a dispatching center. A large power pool will be thus created, utilizing existing transmission facilities into which all generation by both public and privately owned utilities will feed, and curtailment in certain non-defense loads has been prescribed.

Allocation to the South of many large defense projects has increased further the importance of that section as a user of power and the foresight of certain utilities in early extension of their steam generating capacity has prevented a situation that would have been much more acute had full reliance been placed on the vast hydro developments of recent years.

While there does not appear to be any iminent power shortage in other sections of the country, the fact that naval demands are reported to be deferring scheduled turbine deliveries for utility extensions, may make rationing necessary later in other localities. The experience gained in operating the power pool at Atlanta would then prove valuable.

Looking Ahead to Emergency Coal Selection

Two years ago at the Joint Meeting of the A.S.M.E. Fuels Division and the A.I.M.E. Coal Division, in Columbus, the need for a coal testing code was discussed at length. While laboratory testing of coal is prescribed in detail by the A.S.T.M., and the A.S.M.E. Power Test Codes cover the testing of equipment, it was felt that neither fulfilled the functions of a code for testing coal in commercial fuel-burning equipment. Such a code, it was believed, would be helpful to both the supplier and the purchaser of coal.

Accordingly, a main committee and subcommittees were appointed to consider and draft a code. While much in the way of preliminary work has been accomplished, progress has been slow and the need for more basic information dealing with design and operating experience became apparent. It was with this purpose in view that the symposiums on pulverized coal firing and on multiple-retort stokers were scheduled for the recent meeting at Easton.

These symposiums served a further purpose, however, for it was anticipated that during the present emergency situations might often arise in which it would become necessary to burn coals quite different in character from those for which the equipment had been chosen. With selection thus limited it would be most desirable for purchasers to know what changes in operating procedure and adjustments to equipment would be necessary to avoid difficulties that might interfere with production, and for the coal men to have a clearer understanding of the limitations of the equipment in the particular plant in which the coal is to be burned. In this connection it may be pointed out that a plant having different types of equipment is usually limited by what the least flexible will burn.

The papers and discussion at these symposiums contributed much toward a solution of these anticipated problems, as well as affording basic information that should be helpful to the committee that is engaged in preparing the coal-testing code. General agreement among the speakers was apparent.

Supply of Engineers' Now and Later

The demand for men with engineering training has been so stimulated by defense requirements that numerous short intensive engineering courses have been created to deal with various branches of the field. Many of these have been sponsored and financed by the Government, although conducted by recognized schools and universities, whereas others have been initiated as private ventures. Obviously, such short courses do not warrant credit for a degree, but many of them do deserve some form of recognition.

Commenting on this situation, the Engineers' Council for Professional Development observes that "the defense program has highlighted the lack in the United States of facilities for technical education between the engineering college and the vocational school." This is a gap that was long ago recognized and filled by some of the educational systems abroad.

One is led to speculate as to the rôle such training, fortified by experience, will play in the post-emergency situation when the demand for engineers is likely to be greatly curtailed; and to what extent those now receiving limited engineering training will compete with the products of our technical schools. It presents a serious question for those young men now contemplating an engineering career.

Firing with Multiple-Retort Underfeed Stokers

A feature of the joint meeting of the A.S.M.E. Fuels Division and the A.I.M.E. Coal Division at Easton, Pa., was a Symposium on October 30 dealing with "Adjustment of Underfeed Stoker-Fired Equipment." This consisted of papers by representatives of the three leading manufacturers of multiple-retort underfeed stokers in which operation of such stokers was discussed. Excerpts from these papers follow.

Contribution by

GEORGE P. JACKSON, Ch. Engr.

Combustion Engineering Company, Inc.

MULTIPLE retort stokers as manufactured by Combustion Engineering Company are furnished in three principal types, namely, clinker grinder, continuous discharge and dump grate. All are of the same general design with the exception of the moving grates and ash discharge.

The horizontal rams driven by the stoker crank shaft are made in two sizes, and the one selected is based on the maximum coal to be burned per retort. No variation in the length of stroke of the primary rams is provided and the amount of coal fed to the stoker is obtained by varying the speed of the rams. The speed of the secondary rams varies with the speed of the primary rams but the length of stroke may be increased or decreased by means of a stepped cam arrangement. This arrangement permits all of the rams in the retort to be varied in length of stroke as a unit. However, to obtain a more complete control of the fuel bed due to a change in fuel, sizing, etc., the length of stroke of any individual ram may be varied in its relation to the other rams in the retort by controls located at the front of the stokers.

Although the development of the multiple-retort stoker has taken place over a long period, more attention has been given in recent years to a large number of factors that help make it a more satisfactory operating unit. These factors are volume and detail of furnace design, coal sizing, coal selection, distribution of fuel to the stoker hopper to prevent coal segregation, water cooling at sides and rear of the stoker to prevent clinker adherence that disturbs the fuel bed, etc.

Even with the developments in the stoker itself of a better general distribution of air and control of this distribution, and means for a more complete control of the distribution of the fuel on the stoker, our experience has been that fuels such as high-ash, free-burning coals with low ash-fusion temperatures are better suited to the chain grate or traveling grate types of stoker where the fuel bed is not agitated. For the fuel bed to burn out uniformly on the latter types of stoker, it is necessary that a uniform distribution of coal to the hopper be obtained, that the coal be introduced on the grate uniformly and a uniform distribution of air obtained, with air compartment control from front to rear of the stoker. Also, fuels such as lignite, coke breeze and small sizes of anthracite are more suitable to the traveling grate stoker with a comparatively long arch over the rear compartments. The rear arch deflects the burning gases over the fuel bed to the front part of the stoker making ignition more stable and a more rapid penetration of ignition into the fuel bed. This rapid penetration allows a higher air pressure to be used in the front compartments and consequently makes the front part of the grate more effective for burning the fuel. Also, the finer particles that are blown in suspension drift to the front of the grate where they have a better chance of being burned.

The principle of the rear arch arrangement which has been so satisfactorily used for a number of years over traveling grate stokers can be applied to multiple-retort stokers. These arches are most effective on coals that tend to "drift" or lack that quality of "agglutination" necessary to make for satisfactory control of the fuel bed on the grate.

Low Maintenance With Multiple-Retort Stoker

We now have station records that show a maintenance of about two cents per ton of coal burned based over a three-year period for a later installation using air temperatures averaging well above 300 F. This low maintenance is partly due to improved fuel bed and air control but also to a great extent to the grade of fuel used. Therefore, in considering the maximum air temperature that would be practical in normal station operation, the grade of coal to be used should be given consideration.

Combustion rates on the stoker grate may be limited by a number of factors, or a combination of factors, such as cinder emission, slow ignition and penetration, excessive furnace temperatures and clinker adhesions to walls, drifting of fuel to the rear of the stoker, etc., but more often the formation of troublesome clinkers that are difficult to dispose of is the limiting factor. The latter affects the distribution of air to the grate and causes excessive ash-pit losses and high maintenance.

More ample furnace volume and better furnace design with water-cooled surfaces to form the furnace walls have decreased the difficulties from most of the above factors, and higher combustion rates have been obtained with less effort, but satisfactory discharge of the refuse remains, to a great extent, a problem of fuel bed control, air distribution through the grate and a proper selection of fuel.

As stated before, free-burning coals with a high ash content and low fusion temperature, lignites, coke breeze

and anthracite are more suitable for the chain grate or traveling grate stokers.

Coals of a low ash content, that have a tendency to coke or cake, and where agitation tends to break up the fuel bed and make it more porous, are more suitable for the multiple-retort stoker. There are also a number of coals, free burning and with a sufficiently high ash content to amply protect the grate of a chain grate stoker but whose ash-softening temperature and iron content in the ash does not cause serious trouble where the fuel bed is given some agitation. For these latter coals either type of stoker is suitable, and the operator thus has a wider choice. The stoker selection would then probably be based on personal preference or load conditions, considering the multiple-retort type is well adapted for a quick pickup in load.

The proximate analysis of a coal, together with the ash-softening temperature, may be a general guide in the selection of a coal for a multiple-retort stoker, but unless the analysis of the ash is known, as well as the property of "agglutination," it is quite possible that the fuel will not always prove satisfactory. One of the large utility companies makes a practice of including in the analysis of the coals for its stoker plants, the Fe_2O_3 in the ash as well as the initial deformation, fusion and liquid temperatures of the ash. A couple of hundred of these analyses plotted with per cent Fe_2O_3 as ordinates and ash-fusion temperatures as abscissae showed that although Fe_2O_3 generally averaged much higher where the fusion temperature was low, there were also coals where the Fe_2O_3 ranged from 10 to 14 per cent with an ash-fusion temperature of 2100 to 2400 F and with the Fe_2O_3 of 20 to 24 per cent in coals whose ash fusion temperatures are 2500 to 2750 F. Their operating experience indicated that, in general, it was desirable to keep the Fe_2O_3 below 20 per cent on the high ash fusion, and 15 per cent on the coals with lower ash-fusion temperatures.

The ash-fusion temperatures and per cent Fe_2O_3 will generally serve as a good indicator regarding clinkering qualities of a coal, but there are other constituents that may cause difficulties in operation where the iron content in the ash is comparatively low.

In calculating a heat balance to determine the overall efficiency of a proposed steam generating unit, a comparatively high percentage of CO_2 or low excess air for a given exit gas temperature will naturally give the highest efficiency, but in the daily operation, even where the furnace volume is ample, a moderate CO_2 with well-burned-out refuse will usually give the most satisfactory results from an efficiency, reliability and maintenance standpoint.

Due to the variation in the operating characteristics of different coals, the most satisfactory contour and depth of fuel bed can only be determined in actual operation. In general, the freer burning coals require the lesser depth of bed, about 14 or 15 in. above the tuyères over the underfeed section and about 22 to 24 in. on highly coking coals.

For an ideal installation a furnace volume might be specified to give not over 35,000 Btu per cu ft liberation with a furnace which is water cooled on the sides and rear; also, a coal varying in size from crushed coal that would pass a $1^1/_4$-in. screen to slack coal, this to be uniformly distributed across the stoker hopper. This coal would preferably show on analysis from 6 to 8 per cent ash, and have an ash-softening temperature above 2400 F, and an iron content of not over 15 per cent Fe_2O_3.

With combustion rates of about 45 lb per sq ft per hour for a continuous rating and a peak rating under 60 lb for the continuous-discharge and clinker-grinder stokers, and about 85 to 90 per cent of the above for dump grate stokers, the installation should show a high availability and very satisfactory operation.

For the higher ash, low-fusion temperature ash coals and the drifting coals, lower combustion rates are desirable, probably around 35 lb per sq ft of grate per hour for the continuous ratings. Thicker tuyères with larger air openings seem to offer some advantages for the low ash fusion coals.

Some experiments have been carried on by thoroughly mixing coals of various properties before they reach the coal bunkers, and once thoroughly mixed, there would not be much tendency to separate. In this way, a mixture of a low ash coal, a high ash coal and a drifting coal may give more satisfactory overall results than either coal handled alone. This combining of coals to give results that would justify extra expense in operation will require considerable study of the analyses of the coals and the actual results obtained by the various mixtures as they are burned in the furnace.

[In conjunction with Mr. Jackson's paper, John Van Brunt, of Combustion Engineering Company, showed a series of colored motion pictures of firing with multiple-retort underfeed stokers and discussed the various conditions so revealed.—EDITOR]

Contribution by

J. S. BENNETT

American Engineering Company

WHILE this paper deals with the operation of the Taylor multiple-retort underfeed stoker, especially when burning coals with different characteristics, much that will be said applies to all stokers of this type.

The refuse may be discharged by a steam-operated dump plate, through a deep ash pocket with discharge rolls at the bottom or through a gap at the rear of the furnace; the last, known as the continuous discharge type, is increasing in popularity since it costs little more than the dump type and its combustion efficiency practically equals the rotary-ash discharge type.

The Taylor stoker is made with two types of pusher controls. The first type is arranged so that the strokes of all pushers are varied by one adjustment per retort at the front. This suffices for stokers of moderate length and moderate duty. For more severe duty, especially with poorer coals, the straight-line drive type is desirable. Here the stroke of each pusher may be changed without affecting the stroke of adjacent pushers while the stoker is in operation.

Practically all coals, whether friable or not, may be burned effectively on this type of machine with the following reservations:

(*a*) Anthracite gives poor efficiency and limited capacity. The thorough mixture of one-third or more medium or high-volatile bituminous coal with anthracite increases ignition and allows operating results nearly equal to 100 per cent bituminous coal. This feature proved invaluable to coal users during the recent bituminous coal strike, when many underfeed stoker operators burned mixtures rich in anthracite coal.

(*b*) Very low volatile bituminous coals burn satisfactorily provided sufficient grate area is available.

(*c*) Coke breeze can be burned at low rates only unless mixed thoroughly with bituminous coal.

(*d*) It is essential that the stoker and furnace shall be designed for the worst coals to be burned. Low-fusion-ash coals ordinarily require water walls. Refractory overfeed stoker sections, most useful with good coals and preheated air, are subject to chemical damage by coals high in sulphur and iron. With low-fusion-ash coals and preheated air it may be desirable to use water-cooled stokers.

Rating limitations are most difficult to define accurately, but due to their inherent ability to maintain ignition, underfeed stokers can operate throughout a steaming range of 20 to 1 without using oil to maintain ignition.

Excess air is largely governed by the furnace design and by the tightness of the setting, breeching, economizer or preheater. With water-cooled furnaces, CO_2 on the order of 14 to $15^1/_2$ per cent can be maintained, and with lower rates for refractory settings. With economizer and/or preheaters greater losses in efficiency result by air infiltration than by excess air in the gases from the stoker fuel bed. One important exception to this rule is the result of leaky dampers controlling air to the overfeed section, or leaky ash hoppers at the rear of continuous-ash-discharge stokers. Not infrequently air leaks at these points cause otherwise unexplained low CO_2. Dampers and ash hoppers should be inspected periodically to make sure that they are in good condition. Poor CO_2 may also be caused by uneven distribution of coal in the end retorts.

Operation of Pusher and Overfeed Strokes

There are so many operating conditions, types and sizes of coals and stokers that the author is unable to offer more than general rules.

1. Be sure there are sufficient doors for proper observation of the fuel bed. These will usually include the following for narrow stokers and double the number for wider furnaces.

   (*a*) A door in the side wall close to the front wall to observe the shape and condition of the fuel entering the furnace.

   (*b*) For long stokers one door half-way between the front and rear walls.

   (*c*) One big door in the side wall near the point of ash discharge and arranged so that the operator can stand on a platform or the firing floor and observe the fire comfortably. Generally, this door is used to enter the furnace.

   (*d*) Two rear wall doors for narrow stokers; up to six for wide stokers.

   (*e*) Two front wall doors for deslagging where side water walls are not provided.

2. The strokes of all pushers in the same plane must be uniform. The importance of this cannot be overemphasized.

3. Frequent stroke changes should be avoided. Once the proper stroke relationship is determined do not alter it except for occasional modifications to the bottom group, or when there is a pronounced and prolonged change of rating.

4. Generally speaking, the greatest stroke should be used on the top pushers with a gradually reducing stroke down the retort. There are some exceptions to this rule, especially with longer stokers or poorer coals.

5. Don't make radical stroke changes. Frequently, a stroke change of $^1/_4$ in. is all that is required. Remember this may represent a $12^1/_2$ per cent change.

6. See that the coal sizing is uniform across the stoker coal hopper. The ordinary inverted "V" type spreader is a serious offender in this respect. Conical spreaders, swing spouts and weigh larries generally give good distribution. The most careful stroking in the world cannot offset uneven distribution of coarse and fine coal in the stoker fuel bed.

7. Provide sufficient instruments such as underfire and overfire draft gages, CO_2 recorders, etc.

8. Stokers do not require preheated air to predry the coal, but where wet coal is anticipated, provide agitators in the stoker hoppers to insure a reliable coal feed to the stokers.

The fuel bed at the rear of a continuous-ash-discharge or dump-type stoker should be thinner and well burned out so that little combustion will be left in the refuse. Somewhat more active combustion is permissible on the top of the fuel bed above the crusher rolls of a crusher-type stoker as the depth of the ashpit offers an opportunity to burn the combustible before it is discharged to the ash hopper.

Too tightly packed fuel beds or ones that are too heavy may be smoky and matted and will not allow the air to flow through properly. Fuel beds that are thin require more attention and do not provide as much reserve to meet sudden peak demands.

Contribution by

F. S. SCOTT, Stoker Engr.

Westinghouse Elec. & Mfg. Co.

THE Westinghouse Electric & Mfg. Company has developed four types of multiple-retort underfeed stokers, namely, the dump grate, clinker grinder, link-grate clinker-grinder and the link-grate continuous-ash-discharge types.

The best size of low-volatile coals, to obtain optimum performance, is such that 95 to 100 per cent will pass through a 2-in. round-hole screen and 40 to 65 per cent through a $^3/_8$-in. screen. That for high-volatile coal from Pennsylvania, eastern Kentucky and West Virginia, is 95 to 100 per cent through a $1^1/_4$-in. round-hole screen and 40 to 65 per cent through a $^3/_8$-in. screen. For midwestern coal (Illinois, Indiana, W. Kentucky, etc.) 100 per cent should pass through a 1-in. round-hole screen and 40 to 65 per cent through a $^1/_4$-in. screen. There are commercial sizes that fit into these classifications readily.

Low-volatile coal cokes hard; the burning lanes are narrow and long; the flame is usually transparent and short; the fuel bed moves easily; and the clinker formation on the link grate is usually small and friable. Refuse from the underfeed clinker-grinder stoker may be larger and more dense. When the refuse is held in the fire on a dump-grate stoker it will be somewhat larger and more dense than on any of the other three types.

High-volatile eastern coal generally cokes quite hard, making relatively narrow burning lanes although somewhat wider than low-volatile coal. The burning lanes disappear quickly on the link grate, but are usually present at the dump grates or to the pit on a conventional underfeed clinker-grinder stoker. The flame is relatively long and opaque or translucent.

Refuse formation is usually small and friable on link-grate stokers. Coals with very low ash content will make harder clinkers than higher ash coals. Very coarse coal burns quickly and deeply in the fuel bed. The finer sizes can be moved more easily and form smaller clinkers.

High-volatile midwestern coal makes a relatively weak coke and wide burning lanes, which disappear quickly on the link grate. The flame is long, dense and opaque. High rates of burning are conducive to smoke unless secondary air is used. Clinker formation will be larger and less friable than with higher rank coals. The link-grate stokers break up the refuse formation to a much greater degree than do the conventional underfeed stokers.

As the air pressure impressed on the under side of the stoker is increased it tends more and more to lift the fuel bed off the grates. The faster the fuel is burning the smaller are the particles of coke and the less dense is this coke. These all add up to the fact that the limit of the amount of coal that can be consumed in a given time on a given area is the point at which the fuel bed will lift off the stoker in large amounts. This is not a fixed value. Blowing starts at some rate and as this rate is increased more fuel lifts until it is objectionable or insufficient fuel is burned to carry the load.

Very little fly-cinder is produced with underfeed stokers up to rates of about 40 lb per sq ft per hr with eastern high-volatile coal or a "heat duty" rate of about 540,000 Btu per sq ft per hr.

Secondary air is needed at times for high rates and particularly with the lower rank coals. This is introduced through the bridgewall by means of nozzles which may be supplied from a separate fan. If large nozzles, few in number, are used the pressure may be low. If small nozzles are used there should be more of them and higher pressure employed.

Operation

When size segregation occurs across the stoker hopper, the fuel bed will burn unevenly. The coarse coal burns fast and the fine coal slowly. This uneven burning will cause large clinkers and poor efficiency. It can be compensated for, to a considerable degree, by changing the speed of feeding coal to one or more sections of the stoker.

Very wet coal may cause "arching" in the stoker hopper over the main rams so that feeding is uneven. This can be reduced by an agitator in the hopper.

Assuming that there is no size segregation and that the optimum size of coal is being used, the fuel bed over the tuyères will be thinner at the front wall than at the end of the underfeed section. The burning lanes will be straight. They will be narrow at the front and wide at the rear of the underfeed section. The fuel bed over the tuyères may be from 3 to 12 or 15 in. deep depending on the two following conditions:

1. The load or burning rate. The fuel bed will normally be deeper at high loads and thinner at low loads.
2. The type of coal. The fuel bed will be thicker with high rank hard-coking coals than with low rank free-burning coals.

If the load remains constant the fuel bed will be maintained in this form without changes in the adjustments. This condition rarely occurs in practice except in the larger plants. If the secondary rams have too short a stroke the fuel bed will pile up at the front wall. "Mats" and clinkers will form at the front end of the stoker. These formations may be removed and broken up by lengthening the secondary ram stroke.

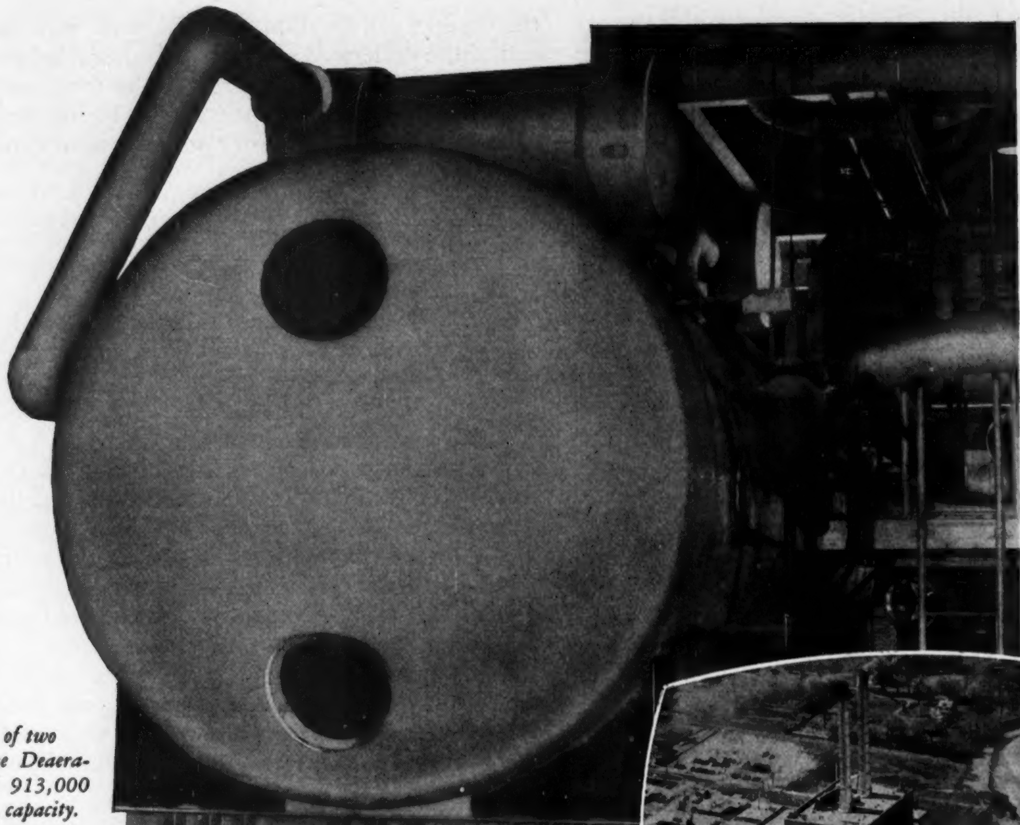
There is one setting of secondary ram stroke that will be best for one load, one air pressure, one furnace, one size of coal and one type of coal. This setting will change whenever any one of the previously mentioned conditions changes.

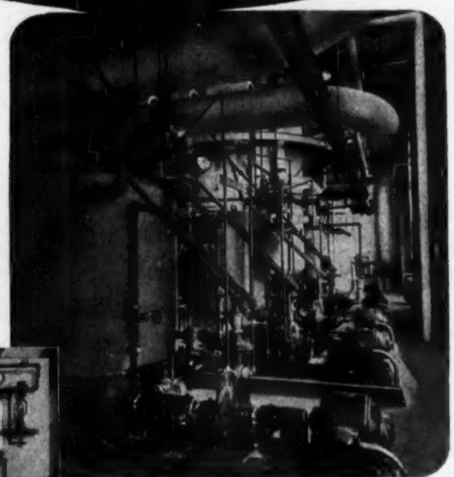
Normally the fuel bed will gradually thin out on the link grate as the bridgewall is approached. The burning lanes from the underfeed section will gradually widen and disappear so that even burning occurs across the width of the stoker. The length of the link grate and its undulating motion cause this change. The fuel bed on such a grate will continue to burn evenly without change in adjustment of the grate action until the load or other conditions change. If other conditions change so that the fuel bed becomes thicker and more rough it may be necessary to increase both the "pushing" and "breaking-up" actions.

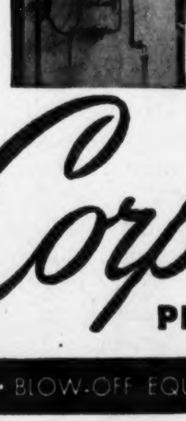
The stoker moves the refuse frequently and in small amounts. The ash discharge plate on a continuous-ash-discharge stoker is set so that an adequate orifice is available for the refuse to pass through, but not so great that coke on top of the refuse can enter the ashpit. This position is changed to suit the size of the refuse which will change along with other conditions.

If the stoker has a clinker grinder, the refuse is moved into the pit above the rolls. The rolls are operated continuously so that a definite level of refuse is maintained. They will be run at various speeds depending on the character and amount of refuse. If they are operated too fast, part of the grates may be uncovered and allow high air flow at this point and not enough air at other points. If they are not operated fast enough or are stopped, the refuse will build up, the clinker formation will be larger, and may extend up the stoker toward the front wall.

The stroke on both the underfeed section and the link grate should be lengthened as the burning rate decreases and shortened as the rate increases. As the load increases the air pressure increases. This pressure tends more nearly to balance the weight of the fuel bed over the grates. There is then less friction between the fuel bed and the grates so that less force is needed to move the fuel bed down the stoker.







Adjustment of Pulverized-Fuel-Burning Equipment

The idea underlying this Symposium at the Joint Meeting of the A.S.M.E. Fuels Division and the A.I.M.E. Coal Division at Easton, Pa., on October 30, was an anticipation that during the present emergency many plants might not be able to acquire the types of coal for which they were initially designed. Therefore, representatives of four leading manufacturers of pulverized-coal-burning equipment were asked to discuss the effects of various coal characteristics and to suggest measures that might be adopted. Excerpts from these contributions follow:

Contribution by

HENRY KREISINGER

Combustion Engineering Company, Inc.

WHEN change of coal becomes necessary or advisable in a pulverized coal installation some of the properties of the new coal, indicated by proximate analysis, size and hardness of the coal, and fusion temperature and composition of the ash, are likely to affect operation of the plant adversely, and some changes in operation or in equipment must be made to offset shortcomings of the new coal.

The processes of generating steam with pulverized coal may be conveniently divided into three main parts each of which is likely to be affected by a change of coal. These are handling and pulverization, burning of the pulverized coal, and behavior and riddance of ash.

Handling and pulverization of coal is affected by size, moisture content and hardness. Size affects the flow of coal from bunker to mill. If the coal contains too much fines, it may hang in the bunker, in the chute, or in the mill feeder and cause interruption. Hanging is aggravated by high moisture content. Shape of bunker, slope of chute, as well as size and shape of hopper above the mill feeder, also affect the flow of coal.

Excessively large size coal generally flows easily from bunker to mill, but may cause irregular feeding or jamming of the mill feeder. It also reduces the capacity of mill.

High moisture content contributes to hanging in the bunker, chutes and mill feeders. It also reduces mill capacity and delays ignition in the furnace. The detrimental effects on capacity of the mill and on ignition can be minimized by supplying the mill with higher temperature air but little can be done to reduce the hanging of coal on its way to the mill.

Hardness affects mill capacity and power consumption. Many hard coals have high volatile content and need not be pulverized as fine as softer low-volatile coals. Hard coals are more easily pulverized when hot and dry. If a mill is short of capacity with hard coal, raising the temperature of the air to the mill 100 deg F may bring its output to the required capacity.

Effect of Moisture and Volatile

The burning of pulverized coal is affected by moisture and volatile content. High moisture delays ignition and makes the fires unstable, particularly at low ratings. Moisture must be first evaporated before the temperature of the coal can be raised to the ignition point, and the time required for the evaporation of the moisture causes the delay in the ignition. To eliminate or greatly reduce this delay in ignition, air at high temperature must be supplied to the mills. With low-moisture coal, a temperature of air entering the mill of 300 F may be sufficient. With high-moisture bituminous coal, an air temperature of 500 F is desirable, and with lignites, 800 F or higher may be required. Therefore, when a change of coal is contemplated the moisture content must be given consideration. There are cases when time and money is spent on changes to the burners with very little improvement in the stability of fire. Better and quicker results may be obtained by providing the mill with higher temperature air.

When the coal enters the furnace the volatile matter comes off as gas which ignites at about 1100 F when this gas reaches a certain proportion in the mixture. Rich gas mixture ignites quicker than lean mixture. The ignitible rich gas mixture is reached quicker in high volatile coal, because more gas comes off, and it may not be necessary to limit the primary air to attain this rich mixture quickly. On the other hand, with low-volatile coals there is less gas coming off, and longer time is required to obtain this rich mixture, and consequently the ignition is slow. It may be necessary to limit the primary air to shorten the time of obtaining rich mixture. At low rating and particularly when the coal is wet it may be difficult or even impossible to reduce the quantity of air through the mill because the velocity of air through the mill and the fuel pipe may be reduced to a point when the air will not pick the coal from the mill and there may

be drifting of coal in the fuel pipe. Furthermore, the amount of heated air supplied to the mill and its temperature may not be sufficient to dry the coal, and delay in the ignition may be caused by the evaporation of the moisture in the coal entering the furnace. There are then two opposing factors, too much air for obtaining rich mixture, and too little air for even flow of the coal from the mill through the fuel piping, and for sufficient drying of the coal. If under such conditions higher temperature air can be supplied to the mill better drying can be obtained, and the larger volume of air due to its higher temperature may provide more even flow of coal from the mill to the furnace. Low ratings with stable fire can be obtained much easier with high-volatile eastern coals and the Illinois coals, than with the low-volatile eastern coals. The extreme in the low volatile is the anthracite which must be dried to very low moisture content, must be pulverized to a high degree of fineness, and the air supplied with the coal to the furnace must be greatly reduced to obtain stable ignition.

After the fuel has been ignited the rapidity of combustion depends on how fast the combustible comes in contact with the oxygen of the air supplied to the furnace. With finer pulverization contacts between the fixed carbon and the oxygen are made more readily and combustion is quicker. Experience has shown that the high-volatile Illinois coal needs to be pulverized to a fineness of 55 per cent through 200 mesh, whereas low-volatile eastern coals have to be pulverized to 75 per cent through 200 mesh for satisfactory combustion. Anthracite requires the highest degrees of pulverization.

Low Volatile Requires Fine Grinding

When change is made from high-volatile to low-volatile coal, the mills should be set for higher degree of pulverization. The finer pulverization can be facilitated by supplying the mill with hotter air which will also improve the stability of ignition. Higher secondary air pressure at the burners producing higher velocity of the air entering the furnace results in greater turbulence, which in turn increases the rate of contact making and the rapidity of combustion.

The behavior of the ash in the furnace affects the operation of the steam generating unit. The fusibility of the ash seems to be the most important property or behavior of the ash.

The spread of temperature between initial and liquid condition may be 100 to 400 deg F. The spread of temperature from the sticky condition to complete liquidity depends on the melting temperature and the proportions of the different compounds. The melting temperature depends also on whether the surrounding gases are oxidizing or reducing. Inasmuch as the temperature of the intense combustion zone is between 2600 and 3000 F, the ash of most coals goes through the liquid state and later when the products of combustion are cooled solidifies.

From the standpoint of ash removal from the furnace, coals having ash with medium fusion temperature—2400 to 2700 F—may be burned with satisfactory results either in slagging or dry-bottom furnaces. Coals with ash melting above 2700 F favor the dry-bottom furnace. However, there are other considerations such as variable load conditions and final disposal of the ash that may make one type of furnace preferable to the other.

When change of coal in a pulverized coal installation is to be made a different behavior of the ash is likely to be encountered. How will this behavior affect the removal of ash from the furnace and setting, and will it be possible to keep the surfaces of the boiler and superheater clean with the existing cleaning facilities? Although some predictions can be made from the known properties of the coal and ash, this question cannot be answered with certainty. Definite answer can be obtained only by actual trial of the new coal.

Contribution by

A. C. FOSTER

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THE problem of burning pulverized fuel involves more than just the burning equipment. Furnace design, location of burners, fuel characteristics—particularly volatile, ash and moisture content—fineness of the pulverized fuel, and primary and secondary air temperature all have their effect on combustion. It is necessary to burn the pulverized fuel with a minimum of excess air consistent with a low combustible loss without flame impingement on water-cooled surfaces and with the combustion completed as soon as possible after the fuel enters the furnace, all of which requires rapid mixing of the fuel and air.

Design of the burners will depend to a great extent upon the design of the furnace which, in turn, will depend upon the coal source, its volatile content and ash-fusion temperature, and whether it is desired that the ash be removed in the dry or molten state. Once the design of the furnace is established, it is not usually subject to any adjustment other than, perhaps, an increase or decrease in the amount of water-cooled surface. On most present-day furnaces, the only adjustment possible is that obtained by decreasing the amount of water-cooled surface by covering some of it with refractory or allowing it to become covered with ash or slag.

Direct firing of pulverized, low-grade anthracite is now as simple as direct firing of bituminous coal. The procedure for pulverization and direct firing of pulverized anthracite does not require any increased operating skill or specialized treatment, despite adverse fuel characteristics including volatile content ranging from $2^1/_2$ to 10 per cent, moisture from 12 to 20 per cent, ash content of 12 to 20 per cent, and grindability of 40 HGU or lower.

The high ash and moisture, and low-volatile content produce a low velocity of flame propagation. To maintain ignition and to sustain combustion under wide and rapid fluctuations in load, it is essential to have fine pulverization and easy control of the primary air-coal ratio. The velocity of flame propagation through a pulverized anthracite-air mixture, as fired, is only from one-tenth to one-eighth of that obtained in air suspensions of bituminous coals and the corresponding maximum amount of primary air per pound of anthracite fired should be only one-tenth to one-sixth of that for bituminous coals. Since approximately the same volume of air is required to carry both fuels out of their respective mills it becomes necessary to remove some of the air from the anthracite mixture after it leaves the pulverizer and before it is discharged through the burners into the furnace. The proper ratio of air to coal is controlled by the use of separating-type burners which concentrate the fuel mixture

by venting out relatively clean air. This air is introduced farther down in the furnace where it augments the secondary air supply. With this system, secondary air is admitted through ports in the front wall and the quantity is regulated by varying either the furnace draft or the position of the secondary air dampers located in front of each air port, or by a combination of both. Flame length is regulated by varying the quantity of vented air. Reducing the quantity of vented air increases the flame length, while increasing the quantity of vented air results in a shorter flame. These same burners may be operated satisfactorily with bituminous coal, which initially was always used for lighting up. However, more recently it has been found that by using oil ignition torches of ample capacity (ten to fifteen million Btu per hour per burner) anthracite may be ignited directly, even in a cold furnace, and it is not necessary, as was first supposed, to get the furnace hot by firing bituminous coal before the anthracite is introduced into the furnace.

Two types of burners are offered by the company with which the writer is associated, for burning pulverized bituminous coals. These are the "Intervane" and "Intertube" types. Both of these burners may be furnished for natural, or forced-draft operation. Either type may be installed to handle pulverized fuel, oil and gas, simultaneously, or separately as desired.

The Intervane burner is a circular turbulent type depending upon the whirling action of the secondary air and fuel to obtain an effective mixture of the two for satisfactory combustion. It is capable of handling a wide variety of fuels from the low-volatile Pocohontas coals to the high-volatile West Virginia and Midwest coals, and Western lignites.

The Intertube type is a turbulent burner for firing horizontally or vertically between tubes of water-cooled furnaces. It may also be used for firing through refractory walls. It is usually used for firing slagging or wet-bottom furnaces where ash is removed in the molten state. This burner is designed to provide uniform distribution of fuel across the width of the furnace so that, by maintaining a blanket of flame over the furnace floor to shield it from the cool side-wall tubes, the maximum temperature for melting slag is obtained. It consists of a wide fantail distributor, which spreads the coal into a broad, thin stream which is divided by the burner nozzles into two rows of jets alternately directed to pass each other without intersecting. Where the streams pass each other, local eddy currents are set up, the velocity of the coal and air is reduced below the velocity of flame propagation, resulting in ignition at this zone. The secondary air is divided into alternately directed jets which impinge upon coal jets traveling in the opposite direction.

Primary Air Control

An important adjunct to the fuel-burning system is the arrangement for control over the primary air quantity going to the burners that is provided at the exhauster inlet. An auxiliary air damper is installed in the mill output control elbow located at the exhauster inlet. This enables the operator to add primary air to that required to carry the coal from the mill, should it be desirable. This provision makes the burners independent of the air flow through the mill and removes the necessity for designing the burners to suit the air flow characteristics of the mills.

Contribution by

OLLISON CRAIG

Riley Stoker Corporation

FOR the purpose of this discussion, it is assumed that the problem is one dealing with completed installations and is not one of initial design. It is assumed further that in an existing power plant there is a boiler and a dry-bottom furnace, and that the furnace receives coal from a unit pulverizer through a conventional burner. The type of coal is used for which the installation was designed and planned. It becomes desirable at some later date to burn a coal different in characteristics from that originally used and certain difficulties are encountered as a result of this change of coal.

The solution of the difficulties arising from this change, by making change or adjustments in the pulverized coal equipment or in the furnace, depend upon the differences in characteristics of the fuels involved. Those characteristics in bituminous coals which are most likely to affect operation when a change in coal is made are volatile content, ash-fusion temperature, grindability and percentage of moisture.

Cause of Puffs and Explosions

If the plant is located in a region where high-volatile coal is most commonly available and if a change is made to low-volatile coal, slower and less stable ignition and longer flame may be experienced. This is particularly true with cold furnaces. The result is to set a high limit on the minimum load that can be carried, experience some increased loss in unburned carbon and affect steam temperature from the superheater.

If unstable flame is experienced, furnace puffs, or so-called explosions, may occur, particularly at low rates of combustion. This comes about through inability of the flame to maintain ignition so that the flame periodically is extinguished, but later relights, when a considerable quantity of coal has accumulated in the furnace. Ignition of this large quantity of coal builds up pressure faster than it can be relieved from the furnace, with consequences ranging from furnace pulsations to practical destruction of the furnace walls. Because of this unstable operation it becomes necessary to operate at higher minimum loads within a range where ignition can be maintained.

The effect of a longer flame is to carry solid particles into the tube bank, chilling the particles below ignition temperature, while they still contain more combustible carbon than would be the case with a shorter flame. Unburned carbon loss is thereby increased. Another effect is to increase superheat in many cases since more heat will be retained in the gases when leaving the furnace.

In many cases the magnitude of these effects might be so small as not to require any action. However, should it be found that the minimum load which could be carried was greater than that which was required by the plant, and which it was possible to carry previously, or should the unburned carbon be excessive or should the final steam temperature be too high, or should puffing be excessive or damaging, it will be necessary to make changes which will tend to promote ignition of the fuel. Generally this can be done, in the case of a cold, water-cooled

furnace, by applying refractory on the side walls in such a way that heat will be radiated from this refractory to incoming fuel at the burners and also so as to reduce radiant heat absorption in this same area.

Compensating for Lower Ash-Fusion Temperature

If any changes or corrections are required due to difference in ash-fusion temperature with the different coals, they will occur in changing from coals having high ash-fusion temperature to coals having lower ash-fusion temperature. If the plant customarily burns coal, the ash-fusion temperature of which is low, it would not be expected that there would be any trouble from ash slagging with coal having ash that fuses at higher temperatures. If, however, the boiler is installed in a location where the most common coal is one having a high ash-fusion temperature, the furnace may have only sufficient water-cooled area to reduce the furnace temperature to just below the temperature at which the ash of this particular coal fuses. If then an attempt should be made to burn lower ash-fusion coal in this furnace, at the same rate as previously, serious slagging can occur. In such cases there is nothing that can be done at a reasonable cost to produce results equal to those with high ash-fusion coals. Certain compromises, however, may be made. If all the wall area has not been covered by cooling tubes, additional tubes may be added. The temperature of gases in the furnace can be reduced by increasing the amount of secondary air, thereby increasing the total weight of gas containing a given amount of sensible heat. However, increasing secondary air increases the loading on forced- and induced-draft fans at a given rating. It may be necessary to accept lower ratings.

Various coals differ in their grindability characteristics. On the Hardgrove scale of grindability, high volatile coals, both eastern and mid-western will usually fall within the range of 50 to 65, some being slightly below and some slightly above these figures. Low-volatile eastern coals will fall somewhere in the neighborhood of 100 grindability. If pulverized coal equipment is installed for obtaining a certain capacity with low-grindability coal, it can then be expected this equipment will be satisfactory with low-volatile coal. In changing from high-volatile to low-volatile coal it will be found that the installed equipment will give greater capacity and greater fineness of pulverization at a given rate. However, if equipment is installed for use with low-volatile coal and only has sufficient capacity to meet required demands with low-volatile coal and if a change is made to high-volatile coal, it will be found that steam requirements cannot be met due to limitations in capacity of the pulverizing equipment. In such cases, the capacity of the pulverizers can be increased by pulverizing the coal to less fineness. To a certain extent this is feasible because high-volatile coal does not need to be ground as fine as low-volatile coal. However, it may be found that it is impossible to pass sufficient high-volatile coal through the pulverizers regardless of fineness, and that as a result steam production is limited.

Moisture affects pulverized coal operation primarily by reducing pulverizer capacity. It may also be of such an amount as to affect ignition. If it becomes necessary to pulverize coal containing unusual amounts of moisture, it then also becomes necessary to apply sufficient heat to the coal in the pulverizer so as to evaporate at least all of the free moisture. Even though this is done, there is still some reduction in capacity, together with increase in power to operate the pulverizer, and there may still be some limitation in ability to produce steam because of excessive moisture. The best answer to this problem is to endeavor to obtain coal which does not contain excessive moisture. The action to be taken to accomplish this depends upon the source of the moisture. Coal may be shipped in open cars and subject to rain or snow. In such cases, open cars can be covered so as to afford protection. Sometimes coal is placed in bunkers which are open at the top. Such bunkers should be covered. Coal may be stored in piles in the open and protection against snow or rain may not be feasible. In such cases drainage should be afforded, coal should be taken from the dryest portion of the pile and in case it becomes necessary to take unusually wet coal from the pile and place it in the bunker, drainage from the bunker should be provided. It can be expected, however, that all plants at some time or other will receive coal which will be extremely wet. For this reason, provision should be made in the initial installation for handling wet coal and obtaining sufficient capacity with wet coal regardless of the location of the plant. To accomplish this, the pulverizer should be of sufficient size and primary air should be supplied to the pulverizer at a temperature which may be required for proper drying.

Contribution by

F. G. ELY

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WHEN burned in pulverized form, the principal differences to be found between coals may be attributed to moisture, grindability, volatile and fixed carbon proportions, and fusing characteristics of the ash. Of these the last is responsible for probably the most disturbing of operating difficulties.

Excessive surface moisture may cause irregular or interrupted feed to the pulverizers, or a reduction in pulverizer capacity for a given quality of product. Such excess should be avoided. Coal spouts and feeder arrangement are sometimes inadequate and may require alteration, but in any case, the operator must be alert to keep coal flowing to the pulverizer during the period of wet coal.

All variations in fuel moisture necessitate control of drying and tempering air to maintain optimum temperature at the pulverizer outlet, at about 140 to 180 F—high enough to assure the evaporation of all surface moisture and much of the inherent moisture, but sufficiently low to avoid coking in the piping and burners.

Inherent moisture is not in itself detrimental to pulverizing, but it tends to retard ignition. When changing to a coal of lower rank, this property may justify the use of higher temperature secondary air, and also higher temperature primary air to evaporate in the pulverizer as much of the inherent moisture as possible.

For a given pulverizer output the higher grindability coals will yield a higher percentage of fines. This greater fineness favors more rapid ignition, and diminishes loss due to unburned particles in the fly-ash. Equivalent fineness can be obtained with the lower grindability coals,

to some extent by increasing the pressure on grinding elements, but beyond this, at a sacrifice of pulverizer capacity, or the requirement of more generous installed capacity. Coarse coal supplied to the furnace not only causes increase in unburned carbon loss, but also tends to aggravate tube slagging because of sustained heating of the ash associated with the fuel particle and because of the reducing action of its combustible matter on the ash constituents.

Broadly speaking, high-volatile coals (30 to 40 per cent) are most readily burned in suspension. Stability of ignition at low loads, and uniformity of flame propagation are definitely superior to lower volatile coals (below 25 per cent). However, the lower volatile coals are likely to be higher in grindability, and their tendency to delayed ignition or to combustible loss is partially offset by greater fineness.

To facilitate the burning of low-volatile coals, several items of design, or of control adjustment, may be exercised, such as,

Increased temperature of preheated secondary air.
Increased temperature of primary air and coal mixture leaving pulverizer.
Decreased ratio of primary to secondary air (richer mixture).
Provision of refractory re-radiating surface in burner zone.

Many features developed in equipment design are advantageous for all ranks of coal, as for example, improvement in multiple-tip burners, and careful arrangement and proportioning of primary air piping to prevent separation of the coal and air mixture as it is supplied to the burners.

It is well known that coal-ash is not a uniform substance, nor even a uniform mixture, and that its content and proportions of refractory and fluxing constituents may vary, even in a given mine and seam, by appreciable amounts. When reduced by grinding to the sizing of pulverized fuel particles, there can and does occur in the furnace a segregation of constituents that produces resultant products very different from the parent mixture in composition and fusing temperature range. A further outstanding factor in the chemistry of slag formation is the state of oxidation of the iron content of the slag, which in the ferrous form (FeO) is one of the principal and most active fluxes, while in the more highly oxidized ferric form (Fe_2O_3) is essentially a refractory substance.

Slagging Control by Excess Air

Control of ferric percentage offers ultimate possibilities of great value. To a limited extent it is already within the ability of the operator, by adjustment of excess air proportions, to accommodate the fusing properties of different coals, which becomes more effective with those having high iron content. In slag-tap operation, reducing the excess air promotes easier tapping. In dry ash units, by increasing excess air, advantage can be taken of high ferric percentage to diminish fusion and clinkering on furnace walls and screens. The influence of this factor is operative to an unappreciated extent in all pulverized coal slagging behavior, and is responsible for many effects that are mistakenly attributed to temperature alone.

The coal-ash softening temperature, as it is usually reported in abbreviated form, is far from adequate for the prediction of slagging tendencies. Analysis covering the full range of fusing temperature in oxidizing as well as reducing atmosphere and determination of the iron content are needed and should be supplemented by further sampling and study of the slags formed in actual furnace operation. Attractive possibilities exist in the use of blended fuels where the shortcomings of one are compensated by the properties of the other, and in such applications more complete analyses are of value.

It is not intended in these remarks to disregard the obvious importance of physical arrangement of furnace and burners, type of cooling surface and facilities for the direct removal of slag and ash by mechanical blowers or hand lancing. These are major factors in design which may be entirely suitable to the plant conditions and normal fuel, but could be altered only at considerable expense. Load factor and the value of service availability often dictate the limitations on range of coal selection. The overall problem, including factors such as these, can be answered only by comprehensive test and evaluation for the specific plant and fuel.

Mobile Power Plants for Navy

The Bureau of Yards and Docks, Navy Department, has ordered two 10,000-kw mobile steam-electric power plants mounted on special railway cars from the General Electric Company to supply emergency power wherever its projects may require. One unit will be located centrally on the West Coast and the other on the East Coast.

The "mobile" power plants will be the first of their kind to be built, but the turbine-generators, boilers, and electrical equipment used in them will be of types proved in service. Each of the units will be housed in two specially built railway cars which can be hauled over the rails at speeds up to 40 mi per hr.

The power-generating car will contain a 10,000-kw turbine-generator and its accessories, a condenser, and the necessary switchgear. The boiler and its auxiliaries, along with a starting engine generating set will be housed in the second car. A mobile substation constructed on a standard car, will be used in conjunction with each generating unit to permit proper voltage to be obtained for any Naval shore establishment. It is estimated that the mobile power plants can be put on the line within 24 hr after they are shunted onto a siding.

Bunker C fuel oil will be used to fire the boilers, and each unit will consume about three tank cars a day when operating at full load. A sufficient fuel supply for two hours' operation will be carried in the boiler cars of each of the units, however, so that they can generate power before the tank cars are hauled up and connected.

The two specially designed cars of each unit will be duplicates. They will embody fabricated welded steel girder construction of the drop frame type. The total weight (about 200 tons) of each car will be carried on eight axles, thereby obtaining an axle loading within the limits of good railroad practice.

The natural circulation-type boiler for each unit will furnish 140,000 lb of steam per hour at 550 lb pressure and 825 F. The turbines will be of single-cylinder design and the generators, operating at 3600 rpm, will produce 60-cycle, 3-phase power at 13,800 volts.

Relation of Suction Head to Capacity with Hot Water Pumps

By F. C. FREEMAN, Engineer

De Laval Steam Turbine Co.

In connection with pumping hot water the question is often asked why is it necessary to have so much head on the suction; why the pump will not work just as well with 10 ft suction head as with 13 ft; and why is it necessary to use a larger pump than would ordinarily be used if the suction head were a little greater? The purpose of this article is to try to answer these questions in a non-technical manner by explaining just what happens when pumping hot water.

To select a centrifugal pump for hot-water service, the net positive suction head must be considered in connection with the vapor pressure corresponding to the temperature of the liquid. Unless the absolute pressure at the eye of the pump impeller is greater than the vapor pressure, some of the liquid will flash into vapor at that point, displacing the liquid in the impeller passages, which, filled with vapor much lighter than the liquid, will not be able to generate sufficient pressure to overcome the discharge pressure. Under these circumstances the pump is said to lose its suction, or to be vapor-bound. The condition is also described as cavitation.

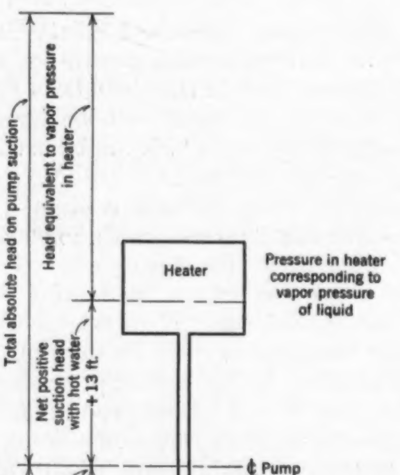

Fig. 1—Pumping hot water at boiling point, but with 13 ft head on the pump suction, is equivalent to pumping 80 F water with a suction lift of 20 ft

The vapor pressure of cold water is so small that it can generally be neglected, and the pressure of the atmosphere acting upon the surface of the water being pumped will force the water up to the eye of the pump impeller located at a higher level. The vapor pressure of hot water, however, may be equal to, or higher than, atmospheric pressure, so that it is not feasible to "lift" the water by "suction" and the pump must be located below the source of supply. Net positive suction head is defined as the static head, measured as the vertical distance of the centerline of the pump below the water level in the open heater or other vessel from which the pump takes its supply, minus the head required to overcome friction and to provide velocity head in the suction line.

Capacity Decreases with Suction Head

The capacity of a hot-water pump decreases as the suction head is decreased, just as the capacity of a cold-water pump drops off with an increase in suction lift, and the performance of the hot-water pump can be predetermined by comparing it with the performance of a cold-water pump operating with an equivalent suction lift. Take, for example, a pump handling water at 212 F, with a net positive head of 13 ft. The pressure in excess of vapor pressure available for forcing water into the eye of the impeller would be the same as with 80-F water lifted 20 ft. This is calculated in the following manner:

The vapor pressure of 80-F water is 0.5069 lb per sq in. which, subtracted from 14.7 lb per sq in. (atmospheric pressure) leaves approximately 14.2 lb, which will lift the water 33 ft. But on the hot-water pump we have a head greater than the vapor pressure by 13 ft

of water column. For the pump handling cold water, atmospheric pressure is greater than the vapor pressure by the equivalent of 33 ft of water column, which exceeds 13 ft by 20 ft. In other words, the hot-water pump would be operating under conditions comparable to those of a cold-water pump with 20 ft suction lift. Similarly, a hot-water pump with 10-ft suction head can be compared with a cold-water pump with 23-ft suction lift. It follows, therefore, that pumps selected for the two conditions must be capable of handling cold water at 20 and 23 ft lifts, respectively. Fig. 1 is a diagrammatic illustration representing the first mentioned example.

Fig. 2 shows how the performance of a 3-in. pump handling cold water is affected by different suction lifts, also the corresponding suction heads that would give the same performance with hot water. While specific for a 3-in. pump, the curves are typical of all centrifugal pumps. It will be seen that the maximum capacity to be obtained from a given pump depends upon the available suction head.

Summarizing, to assure that the proper capacity will be delivered when pumping hot water, it is necessary to

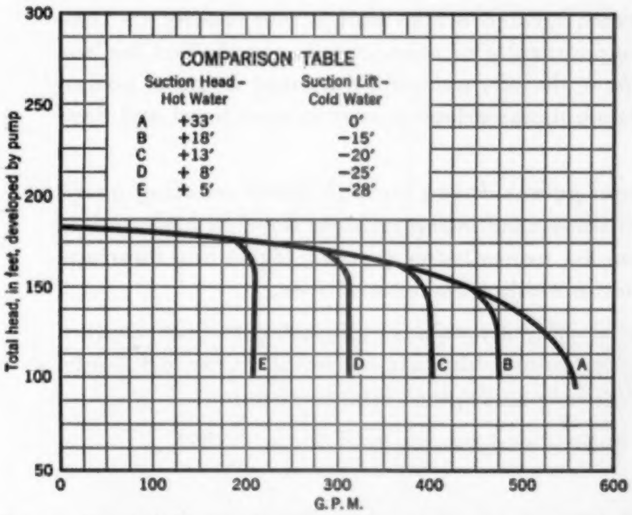

Fig. 2—Head-delivery characteristics of a 3-in. centrifugal pump with various suction lifts, as given in right-hand column of the table. The middle column shows the suction heads required in order to have corresponding conditions with water at the boiling point

have sufficient head on the suction of a centrifugal pump. The difference between 13- and 10-ft suction head may easily mean the difference between delivering full rated capacity and something less. If a given pump will not deliver the required capacity with cold water at a suction lift comparable to the conditions required for hot water, a larger pump must be used.

In most cases hot-water pump performances are not tabulated, but the above comparison provides a simple but practical means for determining the proper size of pump required; that is, for pumping hot water the pump must be of the same size that would be required for cold water when working with an equivalent suction lift—in other words, an excess of net positive head over vapor pressure that is equal to the net excess of atmospheric pressure over vapor plus suction lift in the case of the cold-water pump.

Highest Pressure Turbine Now in Service at Twin Branch

This 76,500-kw cross-compound condensing machine operates at an initial pressure of 2300 lb per sq in. and 940 F steam temperature. Resuperheating of the exhaust from the high-pressure unit raises the steam temperature to 900 F before entering the low-pressure unit. The high-pressure unit operates at 3600 rpm and the low-pressure at 1800 rpm, the generators of each being hydrogen cooled.

THE highest pressure turbine-generator yet to be placed in commercial service by an electric utility recently went into operation at the Twin Branch Station of the Indiana & Michigan Electric Company, near South Bend, Ind.

Built by the General Electric Company, it is designed to use steam at an initial pressure of 2300 lb per sq in. and 940 F temperature. It is a cross-compound machine with an aggregate rating of 76,500 kw, the high-pressure unit operating at 3600 rpm and the low-pressure unit at 1800 rpm. Steam to the low-pressure condensing unit is resuperheated to 900 F. The division of load varies somewhat but from one-quarter to one-third of the maximum capacity of the set will be carried by the high-pressure unit.

As will be seen by reference to the cross-section through the high-pressure unit, standard types of design were adopted to meet the unusual steam conditions and, as a consequence, few difficulties were encountered in manufacturing and placing the unit in service.

The high-pressure turbine embodies double-shell construction. Maximum pressure in the first-stage wheel casing of the inner shell is 1900 lb per sq in. at 910 F. Maximum pressure in the space between the inner and outer shells at full load is 955 lb and the steam temperature from 750 to 840 F. This construction divides the bolting loads between two rows of alloy bolts, and the outer casing is not subjected to temperatures higher than those already experienced. Overstretching at starting and creep at higher loads are reduced by an internal piping system which permits about 75 deg F steam cooling of the inner shell bolts at high loads, and steam heating of these bolts upon starting.

To assure that the shortest buckets of the high-pressure unit will be long enough to maintain good efficiency, eighteen stages of comparatively small diameter are used.

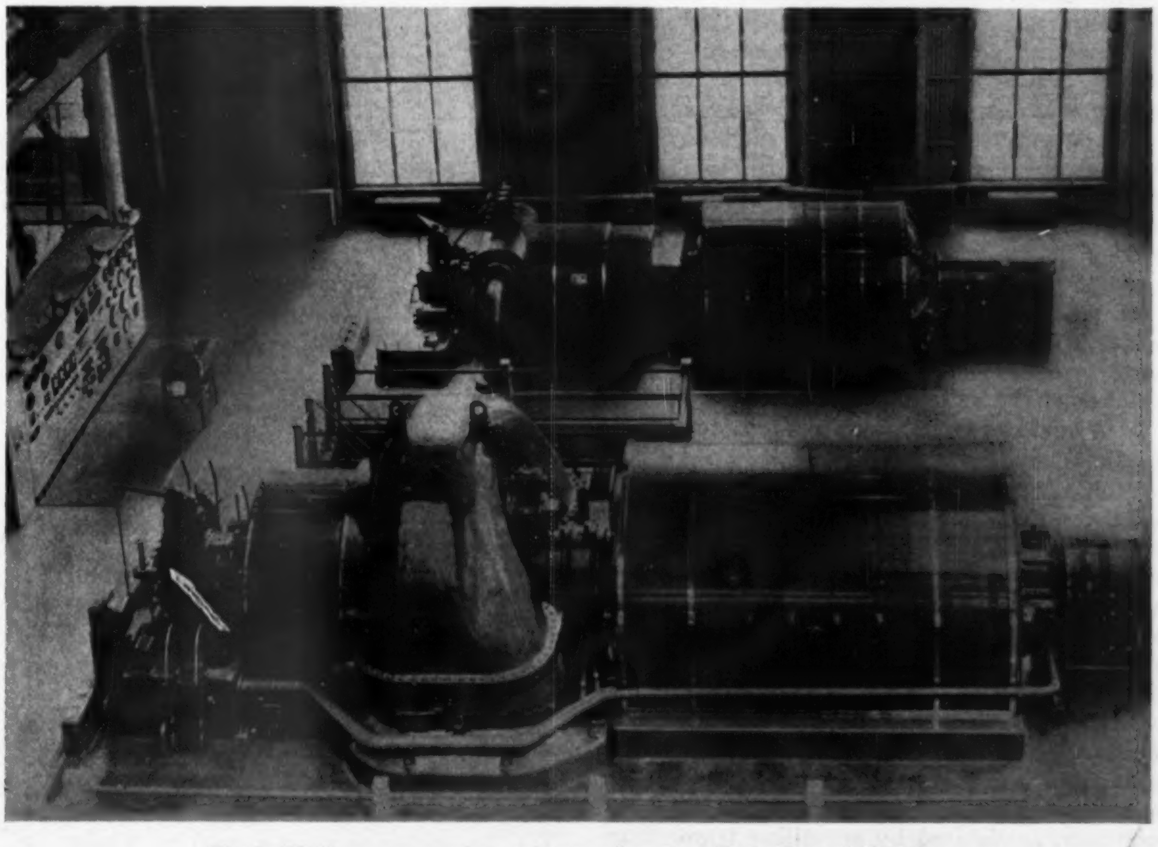

Fig. 1—High-pressure cross-compound unit at Twin Branch Station

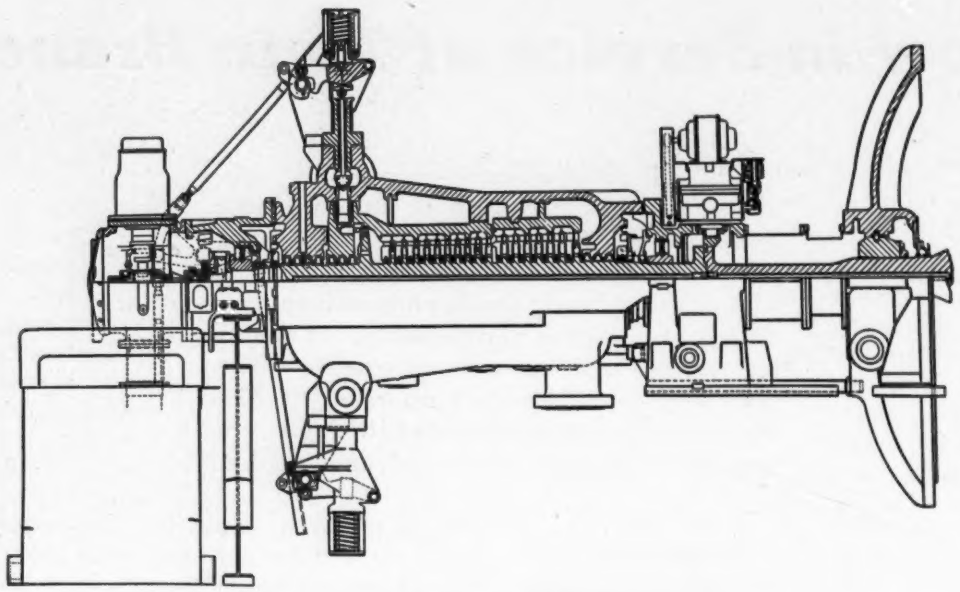

Fig. 2—Cross-section through high-pressure turbine

The first-stage buckets are 0.75 in. in length and steam at full load is admitted through 287 deg of arc. The second row of buckets is 1.06 in. long and steam is admitted around the entire circumference at all loads.

Steam for feedwater heating is extracted from the high-pressure turbine at the eleventh and fourteenth stages, the latter being used for the top heater at higher loads and the former at lower loads to prevent variation in feedwater temperature.

The low-pressure unit, which is of the single-flow, single-casing design, operates on the exhaust from the high-pressure unit after the steam has been resuperheated. It has seventeen stages and is rated at 54,000 kw. Since the pressure varies in proportion to the load on the combined set, no controlling valves were required on the low-pressure unit which operates with full peripheral admission to the first stage at all times. The last stage is exceptionally small and the leaving loss is only $3^1/_4$ per cent at full load and 29 in. vacuum. Efficiency of the low-pressure turbine is maintained at peak value by utilizing superheated steam conditions through the first two-thirds of the unit and by holding the moisture content in the final stage of the unit to not more than 6.5 per cent.

However, if the high-pressure turbine happens to be out of service, it will be possible to operate the low-pressure turbine from the 600-lb steam header supplied by the original boilers in the station. In that case the intercepting valve, required on resuperheating turbines, will serve as a control valve for such individual operation of the low-pressure unit.

The generators of both the high- and the low-pressure units are hydrogen-cooled, thus reducing losses considerably. Both cooling systems are connected to a common treating equipment for extracting hydrogen and air from the sealing oil, and are provided with condensate or service water, as dictated by prevailing temperature conditions.

EQUIPMENT SALES

as reported by equipment manufacturers to the Department of Commerce, Bureau of the Census

Boiler Sales

Stationary Power Boilers

	1941 Water Tube		1940 Water Tube		1941 HRT Type		1940 HRT Type	
	No.	Sq Ft*	No.	Sq Ft*	No.	Sq Ft	No.	Sq Ft
Jan.	170	968,275	62	285,042	89	123,459	51	68,639
Feb.	102	896,763	54	386,356	81	104,622	47	51,474
Mar.	‡133	‡938,605	56	438,980	86	89,324	51	58,529
April	159	802,993	89	476,135	129	151,636	56	50,356
May	134	850,659	101	663,721	114	154,964	75	84,094
June	141	743,762	150	814,210	114	134,880	110	122,026
July	184	1,184,984	111	632,373	94	121,884	89	128,784
Aug.	115	780,119	118	685,212	91	101,284	90	108,680
Sept.	118	867,944	145	944,970	61	63,385	63	65,218
Jan.-Sept. Incl.	1,256	8,034,104	886	5,326,999	859	1,045,438	632	737,800

* Includes water wall heating surface. ‡ Revised.

Total steam generating capacity of water tube boilers sold in the period January to September (incl.) 1941, 81,964,000 lb per hr; in 1940, 55, 956,000 lb per hr.

†Mechanical Stoker Sales

	1941 Water Tube		1940 Water Tube		1941 Fire Tube		1940 Fire Tube	
	No.	Hp	No.	Hp	No.	Hp	No.	Hp
Jan.	77	41,975	24	10,770	94	14,036	104	14,745
Feb.	60	27,736	31	10,729	117	14,774	118	17,862
Mar.	69	31,342	35	17,460	146	21,552	76	12,717
Apr.	75	34,882	36	14,554	147	20,555	87	15,123
May	90	43,971	73	30,930	144	19,267	88	11,402
June	136	50,896	65	15,772	264	42,619	153	21,736
July	113	50,108	86	31,199	290	40,943	189	37,227
Aug.	96	41,882	78	26,202	391	49,547	274	32,209
Sept.	83	33,663	81	39,799	335	49,559	305	41,038
Jan.-Sept. Incl.	799	356,405	509	198,415	1,928	272,852	1,396	194,059

† Capacity over 300 lb of coal per hr.

Pulverizer Sales

	1941 Water Tube			1940 Water Tube			1941 Fire Tube			1940 Fire Tube		
	No.		Lb	No.		Lb	No.		Lb	No.		Lb
	(N)	(E)	Coal/Hr	(N)	(E)	Coal/Hr	(N)	(E)	Coal/Hr	(N)	(E)	Coal/Hr
Jan.	39	—	462,990	10	—	214,250	—	1	1,000	1	—	600
Feb.	42	4	734,200	15	1	186,935	—	—	—	1	2	2,800
Mar.	‡31	3	‡739,700	17	1	317,800	—	—	—	—	—	—
April	14	8	225,740	26	5	270,500	1	—	2,800	—	—	—
May	54	10	777,320	30	5	447,450	—	4	7,000	—	—	—
June	28	24	523,540	21	2	360,270	—	1	1,000	—	—	—
July	57	7	828,640	22	2	454,400	—	1	600	—	—	—
Aug.	30	5	456,480	37	—	705,860	—	1	800	—	—	—
Sept.	38	2	468,930	37	3	1,208,960	—	—	—	1	—	2,800
Jan.-Sept. Incl.	333	63	5,217,540	215	19	4,166,425	1	8	13,200	3	2	6,200

(N)—New Boilers; (E)—Existing Boilers. ‡ Revised.

Turbines for Power Generation from Industrial Gases*

By JOHN GOLDSBURY†
and J. R. HENDERSON†

A discussion of the fields of application for turbines operated by industrial process gases and natural gases. In some cases the reduction in temperature resulting from the expansion through a turbine may be more important than the power thus obtained. Examples are given of the mechanical details of actual turbines which have been built for such applications.

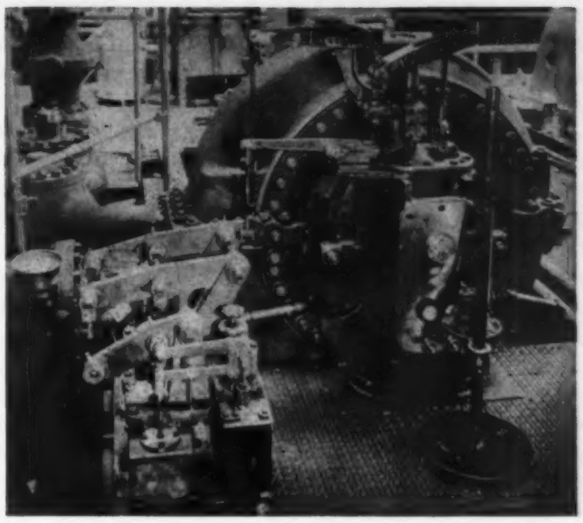

Fig. 1—Flue-gas turbine of 3500 hp on test floor

MANY modern industrial processes involve the production or use of gases or vapors under pressure. It is apparent that certain desirable reactions take place more effectively under pressures above atmosphere. In the case of natural gas, the compression as well as the gas itself is contributed by nature. In any case, when a continuous flow of gas is available under pressure above atmosphere, it will be well to consider whether advantage cannot be derived from expanding the gas through an elastic fluid turbine.

This term elastic fluid turbine is used to denote the general class of turbines which are operated by the expansion of any gas or vapor. The general features are the same as those of the steam turbine, but the dimensions, materials and design details will be determined by the particular elastic fluid used as well as by the pressures and temperatures involved.

In some cases certain difficulties may arise, such as corrosiveness of the gas, presence of liquid, gummy or solid particles carried by the gas or arising from physical or chemical changes, etc. If, however, the advantage of using the gas in a turbine is great, ways of overcoming these difficulties can frequently be found.

In general, the justification for a turbine would be the power which it could produce, but an increasing number of processes are being considered in which the advantage of the turbine is the reduction in gas temperature due to the energy absorbed by the turbine. At least one such application has been made and several others have been considered.

* Excerpts from paper before A.S.M.E. at Louisville, Ky., October 16, 1941.

† Turbine Engineering Department, General Electric Company, Lynn, Mass.

The most important development so far in the use of turbines driven by industrial process gases other than steam is found in connection with certain catalytic petroleum refining processes. In these processes carbon is deposited on the catalyst. The carbon must be burned off and the catalyst regenerated at frequent intervals. In several of these processes it is apparently most effective and economical to burn off the carbon under pressure. In some cases the pressure is as high as 300 lb and much higher pressures have been proposed. Several catalyst retorts are frequently used so that one or more can be undergoing the regeneration processes continuously. The maximum regeneration temperature is controlled either by tubes through which a coolant is passed or by recirculation of some of the products of combustion which have passed through a waste-heat boiler or by other suitable means. There is, then, a steady flow of these products of combustion or flue gas which is of no further use to the process. The heat could, of course, be partially recovered in a waste-heat boiler or other type of heat exchanger, but the pressure potential would be largely wasted. Fig. 1 shows a 3500-hp flue-gas turbine on the test floor, and a cross-sectional view through this turbine is shown in Fig. 2.

Rotor and Casing Materials Selected to Resist Corrosion

With some grades of process charge sulphur will be deposited on the catalyst. This will appear as SO_2 in the flue gas. In order to avoid corrosion from this, as well as from any other possible corrosive component in the gas, it was decided to make the rotor, buckets, nozzles and some other parts of this particular turbine of a high grade of stainless steel, while a low alloy steel was used for the casing parts. Valve trim was of stellite, interior packings were of a special cast iron and outer shaft packings of carbon. Recent tests have indicated that less expensive and more easily workable materials will probably be suitable for many of the parts when the corrosive components of the gas are only SO_2 and water.

As further protection against corrosion it is planned so far as possible to operate the turbine only at exhaust

temperatures well above the condensation points of any acids likely to be present in the gas. When the turbine is to be shut down for any extended period, hot dry air or neutral gas will be blown through the casing, packing glands, valves, etc., to purge out all traces of the gas, and precautions will be taken to prevent any gas from leaking into the turbine during such periods.

Although no solid materials in appreciable quantities are expected to be entrained with the gas, provision has been made for the admission of air to the shaft-packing glands, if that is necessary to prevent such material from settling in the packings. Space has been allowed for assembly of special interstage packings which can also be sealed with air if experience indicates the need for such an arrangement.

Because of the large coefficient of thermal expansion of the stainless steel rotor, it was necessary to use particular care in designing packing and other clearances to prevent any possibility of rubbing, even under large and rapid changes in load or operating conditions. In general, the turbine was designed for simplicity and ruggedness rather than highest efficiency. The first of the three stages is velocity compounded with two rotating bucket rows and with circular nozzle ports. Maximum turbine efficiency, together, doubtless, with other refinements contributing to plant economy, can come later when the experience necessary for determining the best overall arrangement is available.

The control mechanism is such that speed can be held constant at any set value within the setting range of the governor, in this particular case, from 2800 to 4000 rpm. The speed governor controls a single admission valve through an oil operating cylinder, and, in order to assist the speed governor in holding constant speed despite large variations in gas main pressure, a constant pressure governor is used to control the pressure ahead of the speed-governor valve. The pressure governor controls a valve which bypasses excess gas around the turbine. Fluid restoring links permit very close net speed and pressure regulation combined with instantaneous regulation broad enough to be stable.

This particular turbine was designed to be installed out of doors, and the sheet metal lagging, oil tank cover, etc., were consequently made weatherproof.

Control for Second Unit

In Fig. 3 is shown the control diagram for another flue gas turbine of 885 hp capacity. In this case a 1460-hp steam turbine is coupled to the same shaft for starting and for supplementing the gas turbine power. It will be seen that both turbine admission valves, *b* and *d*, are controlled by one speed governor *a* through oil relays. The linkage is arranged in such a way that the gas-turbine valve *d* opens first, the steam-turbine valve *b* then opens to the extent necessary to make up the difference between the load required and the power which can be obtained from the gas turbine under the particular conditions considered. The steam valve has an overtravel in the closed position, so that it does not lift above its seat until the gas valve is nearly wide open

Although there is only one speed governor, a separate emergency overspeed governor is provided on each turbine, to prevent runaway of either turbine with loss of load. The emergency governor *f* on the gas turbine will dump the oil pressure from the gas admission valve cylinder *e* only, while the emergency governor *g* on the steam turbine will dump the oil pressure from both the gas *e* and steam *c* admission-valve cylinders, to cover the case of complete loss of load on the compressor.

The governing mechanism also includes a device, not shown on the diagram, to admit a small steam flow to the

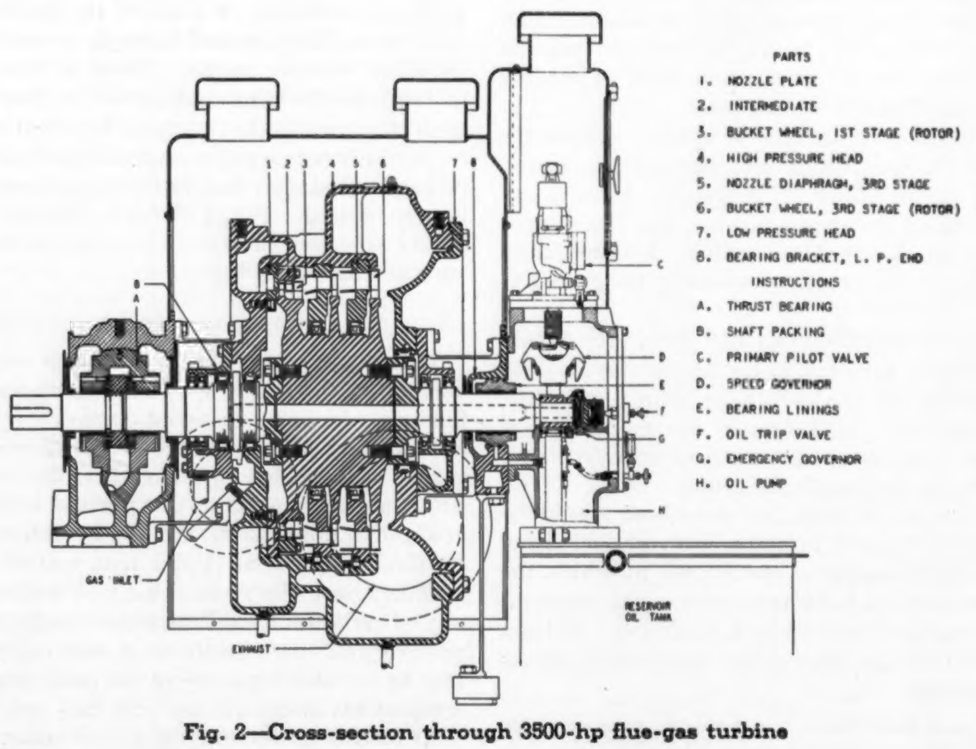

Fig. 2—Cross-section through 3500-hp flue-gas turbine

steam turbine to carry away the heat resulting from windage of the buckets. This rotates idly while the compressor is being driven by the gas turbine. Steam is also supplied to the shaft seals of the gas turbine to prevent leakage of gas. The speed setting of the governor *a* can be regulated either automatically by the pressure control *h* or manually by the handwheel *i*.

Application to Natural Gas

Another large potential field for power from expansion of gas-through turbines is the natural gas industry. It has been calculated that the total work which might theoretically be thus extracted from the annual production

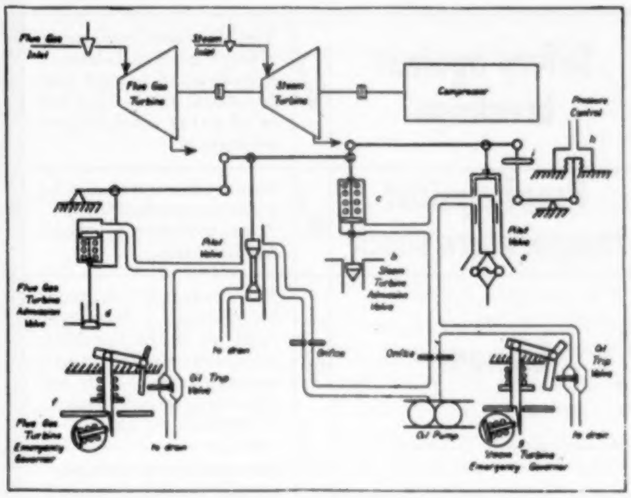

Fig. 3—Governing mechanism for dual drive flue-gas turbine and steam turbine-compressor set

of natural gas in the United States is of the order of one and three quarters billion kilowatt hours.[1] Numerous very small turbines of standard steam designs are being operated by natural gas and used to drive pumps and other apparatus. However, there are undoubtedly many cases where no power is derived from expansion of the gas, but where the pressure drop from the well to the point of use is much greater than is really needed to overcome the friction losses that exist in pipes of reasonable size.

In the repressuring process of liquid extraction from natural gas, well pressures run from 1500 to 3000 lb per sq in. or more while the pressure in the absorption tower is usually from 1000 to 1500 lb. Since the amount of liquid extracted increases with decrease in temperature, any power extracted by passing the gas through a turbine would contribute also to the yield. The turbine could be designed to separate out a large portion of the liquid from the gas by centrifugal force, and might thereby replace one or more of the extraction devices normally used.

Taking, for example, a case where 50,000,000 cu ft of free gas per day are processed with a gas main pressure of 2000 lb per sq in. dropping down to 1000 lb at the absorption towers, if we assume a temperature of 100 F at the main and a net pressure ratio of 1.8 for the turbine after allowing for pipe losses, the net power obtainable will be approximately 650 hp.

[1] Based on 1939 production of 2435 billion cubic feet—*World Almanac*, 1941.

The temperature of natural hydrocarbon gas as it issues from the wells is very low compared with that of combustion gases. It is frequently less than 120 F. When such gas is expanded through a turbine, the temperature at the outlet may be below freezing. This not only requires the use of materials which retain their ductility and strength at such low temperatures, but also introduces a possible difficulty from ice formation. If considered advisable, moisture, hydrates and even carbon dioxide can be removed from the gas before it enters the turbine.

Necessary Precautions

In one natural gas application where turbines were used to drive electric generators, special precautions were taken to avoid danger from ignition of gas which might leak from the packings. One of these precautions was the use of a firewall between the turbine and the generator. Another was the use of beryllium copper for the trigger of the emergency overspeed governor in order to prevent sparks when the emergency governor bolt strikes the trigger. An explosion-proof speed synchronizing control motor was also used.

There are, of course, other processes than those mentioned in which gases are expanded through turbines, but it would seem probable that very much more can profitably be done along these lines than has been accomplished in the past.

Fuel Situation in South America

By L. LEVITAN* and J. B. CRANE†

The present situation among most of the South American countries is analogous to that existing during 1917 and 1918, except that the fuel demands have greatly increased since then. To make up for the deficiency in imports of coal, due to scarcity of shipping facilities, power plants in Argentine are compelled by government decree to burn large quantities of corn, and in Brazil, whose native coal is of poor quality, much wood, nut shells and coffee husks are burned.

ONE of the writers of this article made his first trip to South America in 1917 to study power possibilities. The trip lasted ten months and took him to Brazil, Argentine, Paraguay, Uruguay, Chile and Peru. At that time there was apparently plenty of water power to generate electricity for all needs, except in the Argentine, but since that time the hydroelectric plants near the centers of population and industrial use have reached the limits of their possible development. In some cases, as near as Rio de Janeiro in 1938, it has been necessary for some industrial plants to install steam-driven power plants. In others, dry periods, as in Venezuela in 1940, have caused restrictions in the use of electric power. The modern industrial plants also require increasing amounts of heat and steam for process work so that the question of fuel has become most important, and thus far fuel has not been located in large quantities at places where it can be used to good advantage and many strange substances are in use for fuel.

The production of oil in South America as given by American Petroleum Institute for 1938 was as follows:

Country	Barrels	Tons (2200 lb) (320 lb per barrel)
Venezuela	190,231,780	27,000,000
Colombia	21,660,718	3,600,000
Trinidad	17,737,061	2,530,000
Argentine	16,375,000	2,380,000
Peru	15,838,610	2,350,000
Ecuador	2,249,744	328,000
Bolivia	107,000	15,600

Oil has been located in Brazil in small quantities and it may be that a survey of the Amazon basin will show large quantities as some of the oil from Venezuela, Colombia and Peru is coming from the parts of these countries which border on this area.

The following facts on coal are from "Coal and Iron in South America," published by the Pan-American Union (1938):

Country	Annual Output, Tons (2200 lb)	Coal Imports	Exports	Estimated Reserves, Tons (2200 lb)
Brazil (A)	883,000	1,575,996	None	Three to five billion
Uruguay	None	418,073	None	None
Chile	2,061,409	7,000	7,000	Two to three billion
Argentine	3,116,635	5,000	None	Five million
Peru	115,000	15,047	None	Two billion
Colombia	350,000	600	None	Twenty-seven billion
Venezuela	6,600	5,000	None	Eight million

Lignite and peat occur in Brazil and Peru but thus far are used only locally.

In parts of Brazil near the forests wood is still used for fuel. The public utility plants at Maceio and Natal burn logs for fuel and a new paper plant in the State of Parana is installing three 1000-hp boilers to burn logs as fuel with a provision later to install stokers for burning coal. Twenty years ago small plants often set out a grove of Eucalyptus trees for fuel and planted new trees to replace those cut down for use in the boilers.

Some of the other materials used for fuel are:

COLOMBIA—Coffee husks and palm-nut shells.

BRAZIL—Cotton seeds, nut shells and coffee husks. (Excess coffee is burned in piles by the Government so that it cannot be offered for sale.)

PERU—Leaves and branches from sugar cane. These are cut off the cane when it is being gathered and usually burned on the ground.

ARGENTINE—This country is the hardest pressed for fuel. There are over a thousand diesel engines requiring nearly all the oil produced in that country. The plants using oil and coal under boilers for producing steam have been required to burn grain for fuel. In January 1940 corn was selling for $20 per ton but exports to Europe were cut off and the price gradually decreased until nine months later it was $9.00 per ton. At this point the price was frozen by the government which requested the industries to use it for fuel and has fixed a price of $4.00 to $5.00 per ton delivered; the government making up the difference to the farmer.

World War Situation Analogous to Present

One of the large central stations supplying power to the City of Buenos Aires had a most difficult time to operate and maintain service to its customers during 1917–1919. The following are extracts from its report.

At that time they were furnishing about 200,000,000 kwhr per annum, with an average load of 23,000 kw and peaks of 75,000 kw. They were using coal on stokers and oil as fuel. In 1917 it had become impossible to count on coal or oil supplies because of shipping difficulties, and it became necessary to burn other substances as fuel. Wood was available in large quantities but was 800 miles from the city with single-track railroads and boats on the River La Plata. Quebracho wood (heavier than water and containing 4000 calories per kilo (8800 Btu per lb)) was available in limited quantities with individual pieces weighing 100 kg (230 lb) each. There was no machinery available for making these into smaller pieces. Other wood of 3000 calories (6600 Btu) of smaller size had to be fired at the same time and even

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† Export Manager, Combustion Engineering Company, Inc.

with this there was not sufficient wood available so that charcoal, corn and bran were used as fuel. Coal and oil were used to help carry the peak loads, and with these fuels the plant carried through, surmounting all difficulties. The accompanying chart shows in interesting detail how this was done.

The following table shows the fuel consumption for August 1918:

Fuel	Tons (2200 lb)	Calories per Kilo	Btu per Lb	Prices per Ton
Oil	1,423	9,700	17,400	$4.60–$51.40
Wood	33,420	3,150 avg.	5,670	3.86– 7.00
Charcoal	1,597	5,300–5,900	9,550–10,610	....
Bran	6,204	3,500–3,600	6,300 – 6,490	5.45– 7.72
Corn	16,193	3,500–3,600	6,300 – 6,490	5.45– 7.72
Coal	None	....	....	3.50– 16.00

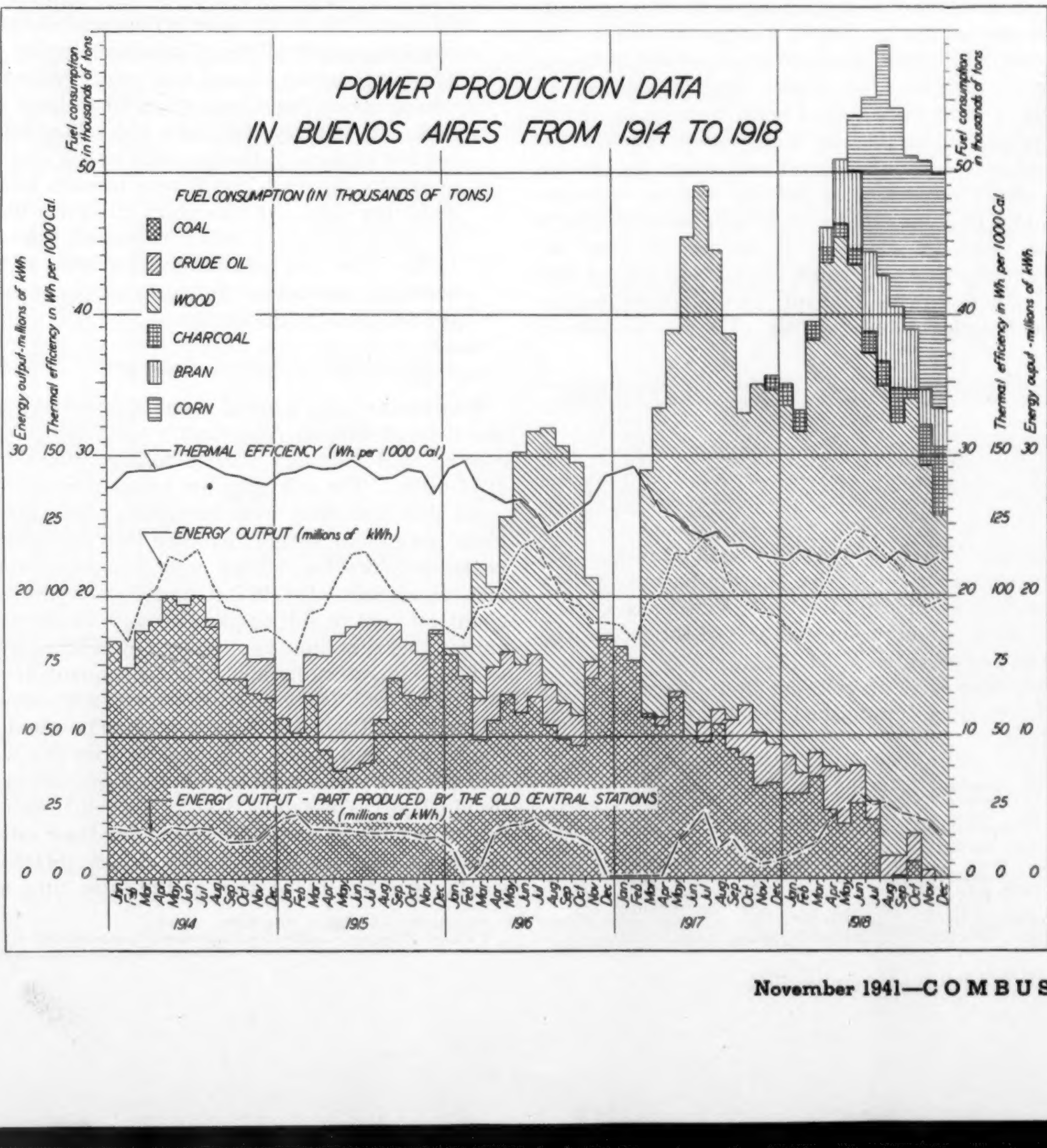
The load of this company has increased to many times what it was in 1919. It has a modern plant operating at 700-lb pressure with pulverized coal as fuel. The older four 50,000-kw turbines employ the reheat cycle with eight boilers each delivering 242,000 lb of steam per hour at 800 F and two reheat boilers each delivering 154,000 lb per hr and reheating the exhaust from the high-pressure units to 800 F. The new section of this plant now under construction has a 50,000-kw single turbine for steam at 900 F which is supplied with steam by two 286,500 lb per hr bent-tube boilers.

They are already burning 1000 tons of corn daily by grinding it in the present coal mills and mixing with the pulverized coal. They have on order eighteen mills, such as employed in this country for making corn flour, which will be used to direct-fire two of the older boilers and one of the new ones. The piping from the mills and the burners must be increased as twice the amount of fuel must be burned to secure the same capacity.

In one of the cement plants in Argentina bran is being used as fuel for the kilns instead of oil. In some other industrial plants corn-on-the-cob is burned in Dutch ovens because sufficient grate area is lacking under the present boilers to produce the ratings desired. In other plants shelled corn is being burned on underfeed stokers by speeding up the stokers.

The Argentine government is now considering taking over the Italian ships in its harbors to bring coal from the United States in order to provide sufficient fuel for the gas plants and such other uses as cannot be taken care of by burning grain.

In Brazil a new steel plant is expected to be in operation about April 1943, and the Brazilian coal mines must be in a position to more than double their capacity. The State of São Paulo now has a greater yearly volume of business from its industrial plants than from its coffee crop and this is rapidly increasing. The sugar industry in Brazil is, next to Cuba and the United States, the largest in the Western Hemisphere. Each of the South American governments has organized a *Fomento Industrial* to have the government foster those industries which promise to aid in the country's development and this will mean not only equipment from the United States but a continued supply of fuel to keep them running.



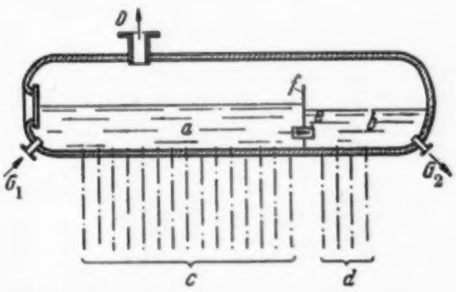
STEAM ENGINEERING ABROAD

As reported in the foreign technical press

Reduction of Salts Content of Steam by Multistage Evaporation

An article in *VDI Zeitschrift*, Vol. 84, No. 42, summarizes various American and European means for reducing the salts content of steam delivered from the boiler drum. Of particular interest is one arrangement which employs multiple-stage evaporation. The boiler-water circulation is divided into several independent circuits, the overflow from one serving as the feed for the next. Thus there is an increase in the concentration from stage to stage and the blowoff water is taken from the last stage. The steam spaces of the several stages may be interconnected and steam is removed from the first stage.

Referring to the sketch, this shows the simplest arrangement employing only two stages of evaporation. The water space of the first stage is represented by *a* and that of the second stage by *b*. The steaming tubes of these stages are represented, respectively, by *c* and *d*. Overflow is at *e* and *f* is the division wall between stages. Feedwater enters at G_1 and is blown off at G_2. The steam outlet is at *D*. It is stated that with a moisture content in the steam of 0.5 per cent and a specified solids content for the steam of 5 mg per liter, with feedwater containing 100 mg per liter, the blowoff is approximately 3 per cent as compared with 10 per cent for the usual arrangement under corresponding conditions.



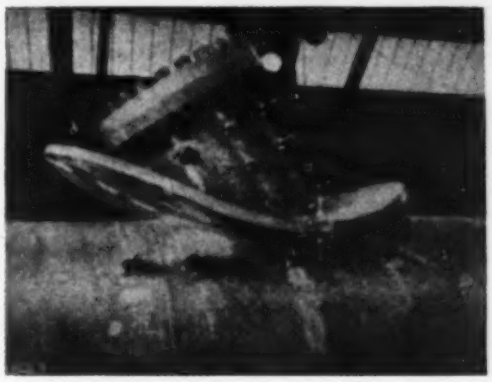
Boiler drum with two-stage evaporation

Tests have indicated that a definite minimum alkalinity must be maintained in the first stage, and water-level indicators are required for each stage and must be watched by the operators. It is observed that stage evaporation will influence the salt content of the steam only where the salts are entrained with moisture.

Stiffening of Branch Connections

When the walls of hollow bodies are interrupted by apertures such as manholes or branch connections, there appear increased stresses which may lead to rupture unless suitable means are provided to afford increased strength at these locations. In the case of manholes and the like, these increased stresses are met by reinforcing rings or by thickening the metal section. The problem becomes more difficult with branch connections and, in order not to interfere with the flow of fluid within the pipe or fitting, reinforcing must be applied externally. The problem is even more difficult when the branch connection is at an angle. Heretofore, the usual practice has been to provide reinforcing ribs, but these add materially to the weight of the fitting.

A different means of meeting this problem has been developed by Sulzer in Winterthur, Switzerland, which is described by H. Le Comte in *VDI Zeitschrift* of February 15, 1941. This involves a welded-on collar construction, based on analysis of the resultant of the longitudinal and circumferential stresses. Referring to the illustration, the inner edges of the collar follow the line of intersection of the branch connection with the main pipe, and its cross-sectional area lies within the plane of the resultant stress.


Branch pipe provided with reinforcing collar

Elongation measurements made on such a branch connection verified the correctness of the calculated stresses. The test piece, which was loaded to destruction, showed a safety factor of 4.9.

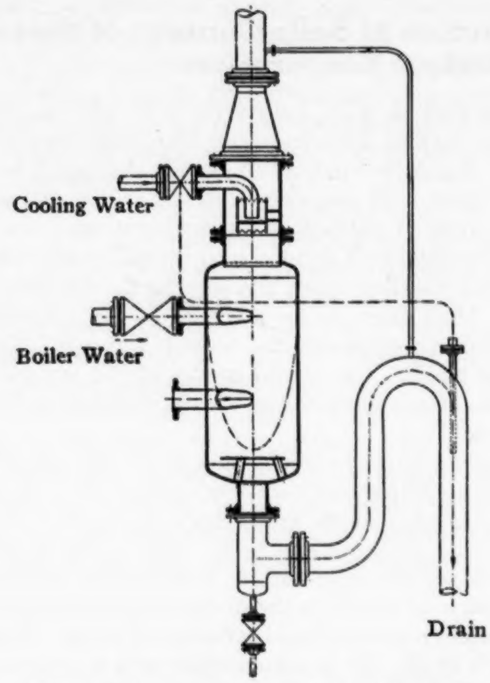
A comparison of weights between this collar reinforcement and the usual ribbed construction gave a reduction in weight for the former of ten to twelve per cent. The welding stresses are relieved by heating.

Silent Blowoff for Boilers

The sketch represents a German design of blowoff, described in *Archiv für Wärmewirtschaft und Dampfkesselwesen* of May 1941, for which silent operation is claimed.

The apparatus consists of a cylindrical drum, approximately 20 in. diameter and 40 in. high, into which the blowoff water is directed tangentially. This results in a circular movement which is said to assure good steam release from the water. The rising steam contacts the

cooling water in the upper portion of the apparatus and is beaten down and condensed. The cooling water is admitted to and uniformly overflows a basin having V-notched overflow edges. This water and condensed steam mixes with the hot water in the lower part of the drum at a resulting temperature of about 140 F, which is not injurious to tile drain pipes.



Expansion apparatus for boiler blowoff

On test this apparatus was able to handle 17,650 lb of boiler water per hour at a temperature of 410 F and 356 lb per sq in. pressure.

Steam Conditions in British Industrial Plants

Replying to a previous article by David Brownlie in *The Steam Engineer* of August 1941, which advocated higher pressures and temperatures for industrial power plants, A. F. Webber, in the October issue of that magazine, defends the preponderance of Lancashire boilers and low-steam pressures among English industrial power plants.

Granting that the majority of such installations may be obsolete, as measured by modern standards, he contends that in most cases the operating savings through replacement would not provide sufficient return on the investment, unless, of course, the plant were in such poor condition as to make scrapping expedient. In that case a plant designed along improved lines would warrant consideration.

Mr. Webber points out that the capital cost per unit of steam increases with pressure and temperature, that in the higher ranges heat recovery equipment is usually required, that automatic combustion control and full instrumentation are desirable and that much more complex feedwater conditioning is a necessity. Thus, the economies of high pressure and high temperature become increasingly less as the size of plant decreases. Further-

more, while it is advantageous to employ regenerative feedwater heating with a large turbine the added complexity of heaters, piping and valves would not be justified for a relatively small plant.

Selecting a hypothetical turbine installation of reasonable size (rather above the average) with 225 lb pressure, 650 F initial steam temperature, 30,000 lb per hr extraction at 15 lb gage, $28^1/_2$ in. vacuum and an electrical load of 2000 kw, Mr. Webber proceeded to show that 1130 kw would be generated by the steam before extraction, leaving 870 kw to be produced by that going to the condenser. This would be about 10,250 lb per hr, giving a total steam flow through the turbine of 40,250 lb per hr.

Such a steam demand, he contended, could easily be met by three Lancashire boilers, each of 13,500 lb per hr capacity; or if water-tube boilers were to be employed two of 20,000 to 25,000 lb per hr rating, with a third as a spare would be required. Such a boiler installation would need no special feedwater equipment or superheat control and the overall cost of steam and power would be less than if the plant were designed on modern power-station lines because the fixed charges on the initial investment would be much smaller.

He concludes by agreeing that higher steam conditions of 350 to 500 lb and 750 F may be justified for large industrial plants but points out that there are relatively few in that class in England where conditions are quite different from those in the United States upon which Mr. Brownlie based many of his contentions.

NEW CATALOGS AND BULLETINS

Any of these publications will be sent on request

Automatic Combustion Control

The Hagan Corporation has issued a new 8-page bulletin (DR-39) describing its system of automatic combustion control for boilers using different methods of firing. Five typical installation diagrams are given which illustrate the application of Hagan control to stoker-fired, pulverized-fuel fired and gas- or oil-fired units.

Boiler Fittings

The Ernst Water Column & Gage Company has just issued a 30-page illustrated catalog describing its line of water columns, gages, try cocks and other steam specialties. Adjustable vertical and inclined water gages of the split-gland type are featured for 300, 450 and 600 lb WSP; standard types for 300 and 400 lb. WSP; and drop-forged steel water gages for extreme pressures up to 1000 lb at 1000 F. The try cocks listed are designed for steam pressures up to 450, 650 and 1500 lb. Gage glass illuminators, gaskets, glasses and safety guards are also listed.

Centrifugal Compressors

A new 20-page catalog (No. 458) issued by the B. F. Sturtevant Company describes its latest designs in large volume, high-pressure centrifugal compressors. This profusely illustrated catalog covers all phases of design, construction and application of the company's Design 14 centrifugal compressor, together with information on methods of drive, lubrication and control. Sectional assembly drawings and a typical performance curve are also given.

Nickel Alloys

A 12-page catalog has just been issued by the International Nickel Company which gives the individual characteristics, mechanical properties and application information concerning twelve different Inco nickel alloys. This bulletin is illustrated and includes tables of physical constants and available forms.

Electrical Controls for Chemical Feeders

A 6-page folder (Publ. 3015) issued by the Cochrane Corporation describes its line of electrical controls for proportional chemical feeders for water-conditioning equipments. Typical control applications are described and two flow diagrams are given.

Indicating and Recording Instruments

The Permutit Company has just released a 20-page bulletin (R-40) describing its line of Ranarex instruments for measuring CO_2, specific gravity of gases, quality of furnace atmospheres, composition of engine exhaust gas and other special uses. The mechanical principle on which the Ranarex operates is described and its application to the burning of coal, oil and gaseous fuels is discussed. The text is accompanied by charts and halftone illustrations and a drawing showing mounting dimensions is also given.

Rail Clamps

The Robins Conveying Belt Company has just issued an attractive 3-color catalog describing its line of rail clamps for single and double rail movable structures. These clamps include both manually operated and automatic types, some of which are equipped with self-adjusting, self-tightening features and designed to withstand a horizontal pressure ranging from 20–25 tons to 40–50 tons (single rail) and from 60–70 tons to 80–100 tons (double rail). This 20-page bulletin (No. 114) is admirably illustrated and reflects credit on both printer and publisher.

Refractories

A 6-page folder has been issued by the Harbison-Walker Refractories Company which describes its line of Korundal brand of high-alumina brick. A diagram shows the melting characteristics of four types of alumina-silica refractories and high refractory quality, volume stability and strength are claimed for this product which contains approximately 91 per cent alumina and 8 per cent silica.

Steam Jet Ejectors

A new 32-page bulletin (G-7) entitled "Steam Jet Ejectors" has just been received from the Elliott Company. This is an informative bulletin which explains the theory and operation of single- and multiple-stage ejectors and is well illustrated with shop and installation views. Ejector characteristics are described followed by further sections dealing with factors affecting ejector selection and ejector application. A full-page chart giving air and water vapor mixture data and a pressure-temperature table are also included.

Seam and Spot Welding

Useful information on the technique of seam and spot welding is given in a new 4-page leaflet announced by Westinghouse Electric and Manufacturing Company. Factors affecting pressure, current, and timing are discussed with special emphasis on time of current flow. Synchronous and non-synchronous control applications are treated with recommendations for the proper use of each system. Specifications for aluminum and brass welding are given. Tables list data on seam welding of mild pickled and oiled steel, spot and projection welding.

Water Treating and Testing Equipment

The Bird-Archer Company has just issued an attractive 20-page catalog illustrating its line of water testing equipment, conductivity apparatus, proportioning pumps and chemical feeders. In conjunction with the test sets offered, an outline of procedure is given for each particular test. A price list of chemicals and sundry laboratory apparatus is also given.